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A Review on the Applications and Bioactive Properties of Fucoxanthin Extracted from Brown Algae

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ABSTRACT
Fucoxanthin (FX), as a natural carotenoid, is found in the chloroplasts of brown algae. Due to its unique characteristics and properties, it has attracted the attention of many researchers and specialists in the food and pharmaceutical industries. They have focused on studying its functional traits, such as antioxidant, anti-inflammatory, anti-cancer, anti-diabetic, anti-obesity, and anti-aging properties, to explore its extraction and processing.

This article first examines modern methods used for fucoxanthin extraction, including microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), conventional heat-assisted extraction (HAE), Soxhlet-assisted extraction (SAE), and supercritical carbon dioxide extraction (SC-CO_2). Studies have shown that the resulting metabolites enhance fucoxanthin's biological properties and play a role in its therapeutic and protective activities. Research on the anti-obesity effects of fucoxanthin indicates that this compound reduces insulin resistance (MetS), which is a key factor in obesity and its related complications. Fucoxanthin and its metabolites can inhibit the growth of cancer cells and, through their antioxidant activity, help reduce the negative effects of diabetes in the body. Recent studies on this compound have also observed its beneficial impact on the metabolic activities of the gut microbiome. A review of research findings indicates that fucoxanthin is a highly bioactive compound with great potential for the production of marine pharmaceutical products and dietary supplements, offering significant economic value.

Keywords: Fucoxanthin, Bioactive, Pigment extraction, Brown Algae, Anti-obesity, Anti-cancer, Antioxidant properties, Insulin resistance, Dietary.

1. INTRODUCTION

Fucoxanthin (FX) is a unique carotenoid found in edible brown algae such as *Undaria pinnatifida* (wakame), *Hijikia fusiformis* (hijiki), *Laminaria japonica* (ma-kombu), and *Sargassum fulvellum* [1]. Fucoxanthin is a xanthophyll with a distinctive structure that includes an unusual allenic bond, an epoxide group, and a conjugated carbonyl group within a polyene chain, contributing to its antioxidant properties [2]. In addition to its pigmentation characteristics, fucoxanthin has attracted researchers' attention due to its potential health benefits.

Fucoxanthin inhibits the proliferation of various cancer cells, promotes weight loss, acts as an antioxidant and anti-inflammatory agent, interacts with the gut microbiota to support intestinal health, prevents organ fibrosis, and exerts many other beneficial effects. Therefore, fucoxanthin has a wide range of applications and promising prospects [3]. One of its key bioactive properties is its anti-obesity effect. Research has shown that fucoxanthin may help enhance metabolism and reduce fat accumulation, particularly excess fat in abdominal white adipose tissue (WAT). This occurs by increasing protein expression in adipose tissue, which promotes thermogenesis, leading to higher energy expenditure and fat burning [4]. Furthermore, studies have demonstrated that fucoxanthin exhibits various pharmacological activities, including anti-diabetic, antioxidant, anti-inflammatory, anti-obesity, and anti-cancer effects, among others [5].

2. STRUCTURE AND METABOLISM

Fucoxanthin is a natural marine carotenoid extracted from brown seaweed and classified under the Phaeophyceae class. Its chemical formula is $C_{42}H_{58}O_6$, with a molecular weight of 658.9 g/mol. Fucoxanthin is responsible for various biological activities, such as free radical scavenging, anti-inflammatory effects, acetylcholinesterase inhibition, and inhibition of the amyloid precursor protein-cleaving enzyme. It also reduces neuronal apoptosis and regulates the

PI3K/Akt and pro-apoptotic protein pathways. Additionally, fucoxanthin absorbs blue-green light and emits yellow-green light, with a peak absorption observed at wavelengths of 510–525 nm [6]. Fucoxanthin belongs to the xanthophyll family and exhibits electro-optical properties, making it the primary light absorber in the fucoxanthin-chlorophyll protein complex (FCP). Experimental results indicate that chlorophyll molecules exist as monomers in nature and remain separate from each other [7]. (Figure 1).

Approximately half of the ingested fucoxanthin is not absorbed in the intestine, allowing it to reach the colon. Fucoxanthin supplementation has been shown to significantly alter metabolites, particularly bile acids and indoles, within a simulated human gut ecosystem [8]. Studies on the absorption and metabolism of fucoxanthin in differentiated human intestinal Caco-2 cells have revealed that fucoxanthinol, the deacetylated form of fucoxanthin, is present both in the extracellular environment and within cells, with its concentration increasing significantly in a time-dependent manner. In mammals, dietary fucoxanthin is converted into fucoxanthinol in the gastrointestinal tract before entering systemic circulation [9]. Following oral administration of fucoxanthin in mice, two fucoxanthinol metabolites and one unidentified metabolite were detected in plasma and liver. The conversion of fucoxanthinol to amarouciaxanthin A predominantly occurs in hepatic microsomes [10]. Additionally, fucoidan and fucoxanthin have shown hepatoprotective effects, including increased hepatic glycogen levels and enhanced antioxidant enzyme activity in the liver tissue of diabetic mice [11].
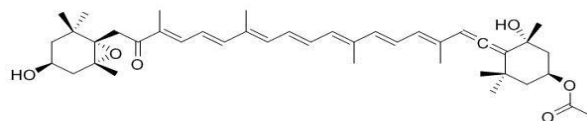

Fig. 1. Fucoxanthin structure.

3.   EXTRACTION OF FUCOXANTHIN FROM BROWN ALGAE

Macroalgae serve as a rich source of bioactive compounds, primarily phenolic compounds, phlorotannins, and pigments. Fucoxanthin is the most abundant pigment found in brown algae, exhibiting multiple beneficial biological activities that enhance its applicability in the food and cosmetic industries. To optimize extraction conditions for maximizing fucoxanthin yield from *U. pinnatifida*, emerging extraction techniques, including MAE and UAE, have been employed. These methods are compared with conventional extraction techniques, such as HAE and SAE. Experimental results indicate that although MAE achieves a slightly higher extraction yield compared to UAE, the fucoxanthin concentration obtained from algae using UAE was twice as high [13]. Additionally, fucoxanthin extracted from U. pinnatifida using $SC\text{-}CO_2$ at temperatures above 120°C enhances thermal isomerization of fucoxanthin. Therefore, high-temperature $SC\text{-}CO_2$ extraction from *U. pinnatifida* not only enhances the health benefits of fucoxanthin via Z-isomerization but also improves extraction efficiency. Moreover, the use of non-toxic CO_2 combined with a low-toxicity organic solvent (ethanol) ensures that the final fucoxanthin extract remains safe for human consumption [14].

The CPC technique is based on the differential distribution of fucoxanthin between two immiscible liquid phases, enabling complete sample recovery without degradation. This process is conducted rapidly and at room temperature [15].

In organic solvent extraction, one of the most commonly used techniques for fucoxanthin extraction, organic solvents such as acetone, ethanol, methanol, and hexane are utilized. The process involves drying the algae first and then immersing it in the solvent to facilitate the release of fucoxanthin from the algal matrix. The advantages of this method include high extraction efficiency and ease of implementation. However, its disadvantages stem from the use of organic solvents, which pose potential environmental and health risks and necessitate additional processing steps to remove residual solvents [16].

4.   BIOACTIVE PROPERTIES

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4.1. Anti-Obesity Effects Of Fucoxanthin

Fucoxanthin, as a marine carotenoid, has garnered significant attention due to its anti-obesity properties and positive effects on weight reduction. The anti-obesity activity of fucoxanthin is attributed to multiple biological mechanisms.

Fucoxanthin has been shown to inhibit lipid accumulation in hepatocyte (FL83B) cells, which serve as a cellular model for fatty liver disease. In an experiment, these cells were treated with various concentrations of fucoxanthin for 24 hours. The results demonstrated that fucoxanthin significantly suppressed lipid accumulation and reduced lipid peroxidation in hepatic cells. Additionally, fucoxanthin downregulated the expression of fatty acid synthase (FAS) while simultaneously enhancing the production of adipose triglyceride lipase (ATGL) and phosphorylation of hormone-sensitive lipase (HSL), thereby promoting lipolysis. These findings suggest that fucoxanthin is an effective marine-derived compound capable of enhancing lipolysis and inhibiting lipogenesis in hepatic steatosis [17].

Thermogenesis and Activation of Uncoupling Protein 1 (UCP1) represent one of the key mechanisms by which fucoxanthin reduces body fat. UCP1 activation plays a crucial role in adipose tissue, promoting thermogenesis, which in turn enhances fat oxidation and energy expenditure. Studies have demonstrated that fucoxanthin is capable of stimulating UCP1 expression not only in brown adipose tissue (BAT) but also in white adipose tissue (WAT), inducing its transformation into a more metabolically active phenotype. Furthermore, fucoxanthin improves glucose metabolism and reduces insulin resistance (MetS), a key factor in obesity and its associated complications. An assessment of fucoxanthin's effects on metabolic syndrome and insulin sensitivity in patients receiving fucoxanthin supplementation revealed significant differences in body weight, body mass index (BMI), waist circumference, systolic and diastolic blood pressure, triglyceride levels, and total insulin secretion [3][18].

4.2. Fucoxanthin As An Anti-Diabetic Agent

Hypogonadism and oxidative stress, commonly observed in diabetic and infertile men, have been linked to metabolic disturbances. In an animal study, fucoxanthin supplementation was found to improve insulin resistance, restore sperm motility, reduce abnormal sperm count, and inhibit lipid peroxidation. Furthermore, fucoxanthin restored mRNA expression levels of GPR54 and SOCS-3 genes in the hypothalamus and normalized luteinizing hormone (LH) and testosterone levels [19].

The long-term complications of diabetes can lead to microvascular diseases, impairing various organ functions and contributing to complications such as diabetic neuropathy, nephropathy, and diabetic retinopathy (DR). Diabetic retinopathy is a major cause of vision loss and blindness among diabetic patients. Fucoxanthin has been shown to ameliorate cellular damage in retinal tissues. Research findings indicate that fucoxanthin reduces inflammatory responses, inhibits apoptosis, and regulates the expression of adhesion factor proteins, thereby preserving the integrity of the blood-retina barrier. Additionally, antioxidant enzyme assays have demonstrated that fucoxanthin's protective effects may be attributed to its potent antioxidant properties [20].

4.3. Anti-Cancer Properties Of Fucoxanthin

Breast cancer (BC) is one of the most commonly diagnosed cancers and remains a leading cause of cancer-related mortality among women. In vitro studies have demonstrated that fucoxanthin and its deacetylated metabolite, fucoxanthinol, effectively inhibit and prevent breast cancer progression [21]. Additionally, a study investigating the anti-proliferative effects of C. calcitrans extract and its fucoxanthin-rich fraction (FxRF) on human liver cancer (HepG2) cell lines revealed promising results. The findings indicated that CME and FxRF extracts induced cytotoxicity in HepG2 cells in a dose- and time-dependent manner. Overall, C. calcitrans extracts exhibited significant anti-cancer activity, with an increase in fucoxanthin content correlating with enhanced apoptotic activity in cancer cells [22].

4.4. Effects Of Fucoxanthin On Gut Microbiome

Fucoxanthin can indirectly influence the balance of gut bacteria and other microorganisms by modulating the metabolic activity of the gut microbiome. Nanoencapsulated fucoxanthin, extracted from *U. pinnatifida*, was stably incorporated into fermented yogurt to enhance its bioavailability. The encapsulated fucoxanthin boosted antioxidant activity, improved milk protein stability in a simulated gastric environment, and stimulated the absorption of small protein fragments in the intestine [23]. Moreover, fucoxanthin isolated from edible seaweed (U. pinnatifida) demonstrated strong inhibitory effects on the growth of Gram-positive pathogenic

bacteria, while showing less effectiveness against Gram-negative bacteria. Additionally, fucoxanthin promoted the growth of beneficial gut microbes in mice. Notably, fucoxanthin can be deacetylated into fucoxanthinol not only by digestive enzymes in the gastrointestinal tract but also by *E. coli* and Lactobacillus species in the gut. These findings suggest that fucoxanthin interacts with and influences the gut microbiome, particularly through its interaction with E. coli and Lactobacillus [24].

5. CONCLUSION

Macroalgae serve as a vast source of bioactive compounds, primarily phenolic compounds, phlorotannins, and pigments. Among these, fucoxanthin is the most abundant pigment in brown algae and belongs to the xanthophyll carotenoid family [7][13]. Among various extraction methods, high-temperature SC-CO_2 extraction from *U. pinnatifida* not only enhances the health benefits of fucoxanthin but also improves extraction efficiency. Furthermore, the use of non-toxic CO_2 combined with a low-toxicity organic solvent (ethanol) ensures that the final fucoxanthin extract remains safe for consumption. Fucoxanthin extracted using this method holds great potential for application as a dietary supplement [14]. Therefore, the importance of selecting an advanced extraction technique, along with the use of green solvents, is crucial not only for aligning with green chemistry principles but also for preserving the bioactivity of fucoxanthin, making it a promising compound for nutraceutical and pharmaceutical applications [25].

Studies have demonstrated that these metabolites enhance the biological properties of fucoxanthin and play a crucial role in its therapeutic and protective activities. As a result, fucoxanthin exhibits high potential for the development of dietary supplements [26]. An investigation into the weight-loss mechanisms of fucoxanthin revealed that bile acid metabolism and gut microbiome modulation could serve as potential therapeutic targets. These findings further confirm that fucoxanthin is a valuable candidate for promoting health and combating obesity [27]. Fucoxanthin consumption has been shown to reduce body weight, BMI, waist circumference, systolic and diastolic blood pressure, and triglyceride levels, while also enhancing first-phase insulin secretion and total insulin release in patients with MetS [18].

Beyond its antioxidant and anti-inflammatory properties, fucoxanthin also ameliorates diabetic symptoms, enhances spermatogenesis and reproductive function in diabetic males, and preserves blood-retinal barrier integrity by reducing apoptosis and regulating adhesion protein expression. Additionally, fucoxanthin alleviates cellular damage in diabetic retinopathy (DR), a leading cause of vision loss and blindness in diabetic patients [19][20]. Furthermore, increased antioxidant activity, enhanced milk protein stability in a simulated gastric environment, and stimulated absorption of small protein fragments in the intestine have been observed in nanoencapsulated fucoxanthin-enriched fermented yogurt [23]. Fucoxanthin also promoted the growth of gut microbiota in mice. It can be deacetylated into fucoxanthinol not only by digestive enzymes in the gastrointestinal tract but also by E. coli and Lactobacillus species in the gut. These findings suggest that fucoxanthin interacts with and influences gut microbiota, particularly E. coli and Lactobacillus, highlighting its potential role in gut health modulation. Therefore, fucoxanthin extracted from *U. pinnatifida* may have promising applications in human health maintenance [24].

Marine plants are a rich source for the discovery of anti-cancer drugs. Growing evidence suggests that fucoxanthin exerts anti-proliferative effects on various cancer cell lines [28]. A study demonstrated that increasing fucoxanthin concentration in Chaetoceros calcitrans extract enhanced apoptosis in liver cancer cells through multiple cellular pathways [22]. Fucoxanthin exhibits a wide range of pharmacological properties, including antioxidant, anti-tumor, anti-inflammatory, anti-obesity, anti-cancer, and antihypertensive effects. Additionally, it inhibits proliferation, invasion, and metastasis of several cancer cell lines [27].

A comprehensive review of research findings indicates that fucoxanthin is a highly bioactive compound with significant potential for the development of marine-based pharmaceutical products and dietary supplements, offering substantial economic value.

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Assessment of Antioxidant Markers and Hatchability in Broiler Chicks Following In Ovo Injection of Vitamin C

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ABSTRACT

Modern broiler chickens are genetically selected for rapid growth and enhanced feed efficiency. However, these advancements often result in increased oxidative stress, which negatively impacts the quality, health, and growth performance of the chickens. Oxidative stress results from an imbalance between reactive oxygen species (ROS) production and the body's antioxidant defense mechanisms, potentially leading to cellular damage. Vitamin C, a potent water-soluble antioxidant, scavenges free radicals by donating electrons, thereby mitigating oxidative damage. In recent years, in-ovo injection of vitamins and other nutrients has been used to enhance the survival and growth of broiler chickens by boosting their antioxidant capacity. This study examines the effects of in-ovo vitamin C injection on antioxidant enzyme activity in broiler chickens. Seventy-one fertile eggs were divided into three groups: the control group (C) with no injection, group one (T1) injected with 3 mg of vitamin C, and group two (T2) injected with 6 mg of vitamin C. Hatchability, chick body weight at hatch, and antioxidant enzyme activity—including glutathione peroxidase (GPx), superoxide dismutase (SOD), catalase (CAT), total antioxidant capacity (TAC), and malondialdehyde (MDA)—were evaluated. The results revealed that hatchability in group T1 was significantly higher than in the control and T2 groups (P < 0.05). Furthermore, the activity of glutathione peroxidase (GPx) and total antioxidant capacity in group T1 was significantly higher than in the control group (P < 0.05). Malondialdehyde (MDA) levels in group T1 were significantly lower than in the control and T2 groups (P < 0.05). These findings indicate that in ovo injection may enhance antioxidant activity, thereby improving chick growth and overall health.

Keywords: Vitamin C, In Ovo Injection, Oxidative Stress, Broiler Chickens.

6.   INTRODUCTION

   In contrast to mammals, birds are equipped with a finite supply of nutrients for embryonic development, which are deposited within the egg through specific maternal mechanisms. Under certain conditions, particularly in modern broiler chickens, this nutrient reservoir may prove insufficient to fulfill the embryo's growing demands, ultimately leading to impaired embryonic growth, reduced hatchability, and compromised chick quality. During incubation, the rate of oxygen consumption rises markedly from the mid-21-day period, largely due to embryonic development. However, in the final days before hatching, oxygen consumption stabilizes. This increase in mitochondrial respiration and oxygen consumption is essential for embryonic development, providing the necessary energy for tissue growth, nutrient transfer from the yolk, and the maintenance of vital functions such as heart rate. Oxidative stress occurs when reactive oxygen species (ROS) production exceeds the body's antioxidant defense capacity, leading to cellular damage. Oxidative stress occurs when reactive oxygen species (ROS) overwhelm the antioxidant defenses, potentially causing damage to critical cellular structures, including proteins, DNA, and membrane lipids. Free radicals, characterized by their unpaired electrons in the outermost shell, are highly reactive and initiate chain reactions by capturing electrons from other molecules in an attempt to stabilize. Vitamin C, the principal water-soluble antioxidant, plays a pivotal role in scavenging reactive oxygen species, including hydrogen peroxide, and neutralizing oxidative damage. As an electron donor, vitamin C converts to dehydroascorbic acid and contributes to various antioxidant processes. Although vitamin C does not directly participate in all biological processes, it is indispensable for the reduction of metal cofactors necessary for enzyme function, such as copper in monooxygenases and iron in dioxygenases. Due to the prevalence of oxidative stress during avian embryonic development, investigating dietary and management strategies to mitigate its effects is essential. While the antioxidant properties of vitamin C have been well-established, comprehensive research addressing its impact on the entire antioxidant profile in broiler chickens remains limited. Consequently, this study aims to investigate the effects of vitamin C supplementation on the activity of antioxidant enzymes in broiler chickens, with the goal of improving chick viability and growth performance.

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6.1. Materials and Methods

Egg Collection
In this study, conducted in 2022, 100 fertile eggs from the Ross 308 strain, with an average weight of 63.5 ± 2.5 g, were sourced from the Mahaan Hatchery located in Tehran Province. The eggs were carefully selected for uniformity in size and quality. After collection, the eggs were stored under optimal conditions to prevent any damage or deterioration before being placed in the incubator.

Egg Grouping
On the fifteenth day of incubation, candling was performed in a dark environment to identify and remove eggs that were either infertile or contained dead embryos. As a result, 71 healthy eggs remained, which were then divided into three groups: the control group (11 eggs), the first treatment group (T1) with 3 mg of vitamin C injection (30 eggs), and the second treatment group (T2) with 6 mg of vitamin C injection (30 eggs).

Preparation of Vitamin C Powder and Its Dilution
For the preparation of the vitamin C solution, 3 g of water-soluble vitamin C powder (purchased from ShimiCenter) was weighed using a precise laboratory balance (model 202GR, AND Company, Japan). The powder was then completely dissolved in 100 ml of distilled water to prepare the stock solution.
For the preparation of required dilutions, 0.1 ml and 0.2 ml of the stock solution were used for the 3 mg and 6 mg vitamin C doses, respectively. These volumes were accurately measured using insulin syringes. Before injection, the final solution was passed through 0.45 µm cellulose acetate sterile filters (Teb Azma Company) to prevent any microbial contamination.

Injection of Vitamin C Solution into the Eggs
Prior to injection, the eggs were disinfected using an antiseptic tincture. The vitamin C solution, with specified doses for the treatment groups, was injected into the anterior section of the egg and the amniotic fluid on the fifteenth day of incubation using an insulin syringe (gauge 28 needle). After the injection, the hole created was sealed with sterile wax to prevent potential contamination. The control group eggs were left without injection in the incubator.

Evaluation of Hatchability and Weight of Hatched Chicks
On the twenty-first day of incubation, after the chicks hatched from the eggs, the number of hatched chicks was counted and their weight was measured using a precise laboratory balance (model 202-GR, AND Company, Japan)

Sample Preparation for Antioxidant Activity Assessment
In compliance with ethical guidelines, the chicks were euthanized using CO_2 gas within a controlled chamber. The chicks were gently transferred into the chamber to minimize stress. The CO_2 flow rate was set to 10-30% of the chamber volume per minute. According to established humane and scientific protocols, the euthanasia process is carried out in multiple stages to prevent undue stress and pain. The initial anesthesia phase, with a CO_2 concentration of 30-40%, lasted approximately 1-2 minutes. Following anesthesia, the CO_2 concentration was gradually increased to 70-100%, resulting in death within 5-7 minutes. After euthanasia, the chicks were dissected, and their livers were harvested for analysis.
For embryos that failed to hatch, the top of the eggshell was carefully broken, and the dead embryos were separated from the egg contents. The weight of these embryos was recorded, and their livers were also extracted using the same procedure as for the live chicks.

For each 100 mg of liver tissue, 1 ml of phosphate buffer (pH 7.4) was added, and the tissue was homogenized manually. The homogenate was then centrifuged for 20 minutes at 6000 RPM (High-Speed Refrigerated Centrifuge, Islamic Azad University, Karaj). The resulting supernatant was collected into 1.5 mL microtubes. The enzyme activities of Glutathione Peroxidase (at 412 nm, via spectrophotometry), Superoxide Dismutase (at 420 nm, via spectrophotometry), Catalase (at 405 nm, via spectrophotometry), Total Antioxidant Capacity (based on a standard curve of ΔOD standard absorbance versus known concentrations), and Malondialdehyde (via spectrophotometry at 532 nm) were quantified using ZellBio 96-well kits (Germany), in accordance with the manufacturer's protocol.

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Statistical Analysis

The hatching rate was analyzed using the Chi-square test, while one-way analysis of variance (ANOVA) was performed for other data. Statistical analyses were conducted using SPSS software (version 26), and differences were considered statistically significant at $P \leq 0.05$.

Results

Hatchability Rate and Chick Weight Measurement

The hatchability rate is presented in Table 1. In the control group (C), the hatchability rate was 81.81%, in the T1 group, it was 93.33%, and in the T2 group, it was 83.83%. The hatchability rate in the T1 group was significantly higher than that of the T2 and control groups ($P < 0.05$).

Additionally, the average weight of broiler chicks at hatching is shown in Table 2. The mean weight in the control group (C) was 43.21 g for live chicks and 18.26 g for dead chicks. In the T1 group, the average weight was 45.33 g for live chicks and 19.78 g for dead chicks, while in the T2 group, it was 42.29 g for live chicks and 17.50 g for dead chicks. Although no statistically significant differences were observed ($P > 0.05$), the average chick weight in the T1 group was higher than in the other two groups.

Fig. 1. Percentage and Comparison of Hatchability in the Three Experimental Groups

Parameter	C	T1	T2
Hatchability(%)	81/81	93/33	83/83

Fig. 2. Average Body Weight of Broiler Chicks at Hatch in the Three Experimental Group

Parameter	C		T1		T2	
Average Chick Weight (g)	Live	Dead	Live	Dead	Live	Dead
	43/21	18/26	45/33	19/78	42/29	17/50

Evaluation of Antioxidant Enzyme Activity in the Liver of Broiler Chickens

The results related to the activity of antioxidant enzymes are presented in Table 3. The activity of the glutathione peroxidase (GPX) enzyme was found to be significantly higher in groups T1 and T2 compared to the control group. Specifically, the activity in the control group was 197.11 ± 11.71 mg/ml, while in T1 and T2, it was 246.61 ± 44.1 mg/ml and 211.33 ± 37.53 mg/ml, respectively ($P < 0.05$).

Regarding the activity of superoxide dismutase (SOD), the results were measured across all three groups. In the control group, the activity was 26.20 ± 2.02 mg/ml, and in groups T1 and T2, the activity was 31.19 ± 2.63 mg/ml and 25.30 ± 2.70 mg/ml, respectively. There was no significant statistical difference between the three groups ($P > 0.05$). However, the activity of SOD was slightly higher in group T1 compared to the other two groups.

For catalase (CAT) enzyme activity, measurements showed that the activity in the control group was 37.87 ± 0.93 mg/ml, while in T1 and T2 it was 40.24 ± 1.11 mg/ml and 36.16 ± 0.53 mg/ml, respectively. Despite the observed differences, there was no significant statistical difference in catalase activity across the three groups ($P > 0.05$). Yet, group T1 had the highest enzyme activity when compared to the other groups.

The total antioxidant capacity was also assessed across the three groups. In the control group, it was 0.26 ± 0.058 mmol, in T1, it was 0.40 ± 0.15 mmol, and in T2, it was 0.33 ± 0.16 mmol. A statistically significant difference was observed between the control group and group T1, with the latter showing higher total antioxidant capacity ($P < 0.05$).

Finally, the malondialdehyde (MDA) levels, a marker of lipid peroxidation, were measured across the three groups. The MDA levels in the control group were 14.70 ± 2.17 µmol, while in T1 and T2 they were 4.10 ± 1.04 µmol and 7.25 ± 0.38 µmol, respectively. A significant difference was observed between the control and T1 groups, with

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lower MDA levels in T1. Additionally, there was a significant difference between groups T1 and T2, with MDA levels being significantly lower in T1 compared to T2 ($P < 0.05$)

Fig. 3. Antioxidant Enzyme Activity and Its Comparison Across the Three Experimental Groups

Parameter	C	T1	T2
Glutathione Peroxidase (Gpx) (mg/ml)	a11/71 ± 11/197	b1/44 ± 61/246	b53/37 ± 33/211
Superoxide Dismutase (SOD) (mg/ml)	a02/2 ± 20/26	a63/2 ± 19/31	a70/2 ± 30/25
Catalase(CAT) (mg/ml)	a93/0 ± 87/37	a1/1 ± 24/38	a53/0 ± 16/36
Total Antioxidant Capacity (TAC) **(mmol)**	a058/0 ± 26/0	b015/0 ± 40/0	a016/0 ± 33/0
Malondialdehyde (MDA) **(µmol)**	a17/2 ± 70/14	bc04/1 ± 01/4	b38/0 ± 25/7

Non-identical English letters in each row indicate a statistically significant difference.

Discussion

In ovo feeding, which involves the direct injection of nutrients into the egg, is an innovative and promising approach for enhancing embryonic development and optimizing post-hatch performance. This technique offers a targeted and efficient method for delivering essential nutrients to developing embryos, potentially reducing the necessity for prolonged maternal dietary enrichment to achieve similar physiological benefits. By enabling precise nutrient administration at critical developmental stages, in ovo injection maximizes the bioavailability and absorption of key compounds, thereby supporting embryonic growth and resilience [4].

It is well established that incubation parameters—including temperature, humidity, ventilation, and egg turning—play a pivotal role in hatchability and chick quality, with temperature exerting the most significant influence. The thermal environment experienced by the developing embryo is determined by three key factors: the incubator temperature, the efficiency of heat transfer between the incubator and the embryo, and the metabolic heat generated by the embryo itself. Nutrient supplementation via in ovo injection may help embryos overcome inherent nutritional limitations, particularly during the late incubation period when metabolic demands peak. Previous studies have reported that chicken embryos experience metabolic heat stress in the final stages of incubation due to increased endogenous heat production. Ascorbic acid has been shown to mitigate this stress by modulating adrenal metabolism, specifically by inhibiting the activity of 21-hydroxylase and 11-beta-hydroxylase enzymes, thereby reducing corticosterone synthesis while promoting the production of mineralocorticoids.

Moreover, ascorbic acid plays a crucial role in maintaining normal immune function during periods of physiological stress in developing chicks. As a potent natural antioxidant, vitamin C has been demonstrated to alleviate the adverse effects of late-incubation stress by downregulating the synthesis and secretion of corticosteroids. Notably, vitamin C is absent in freshly laid eggs and is synthesized endogenously in the embryo only around days 3–4 of incubation. However, under artificial incubation conditions—particularly in the final phase when embryos are exposed to elevated temperatures—the endogenous production of vitamin C may be insufficient to counteract oxidative stress and metabolic challenges [12]. Thus, in ovo administration of vitamin C presents a viable strategy to enhance embryonic resilience, improve hatchability, and support early post-hatch development.

The results of our study demonstrated that hatchability percentage in the T1 group was significantly higher than in both the control and T2 groups. These findings align with previous research [4], which reported that in ovo administration of vitamin C can enhance hatchability, particularly under oxidative stress conditions. Similarly, a study by [12] found that injecting 3 mg of vitamin C into the egg increased hatchability to 93% compared to 74% in the control group, corroborating our results. Oxidative stress, primarily caused by excessive free radical production and cellular damage, is known to adversely affect embryonic development.

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Multiple studies have indicated that in ovo injection of vitamin C, as an effective anti-stress agent, positively influences hatchability, embryonic growth at various incubation stages, and post-hatch chick weight [11]. Zhu et al. (2021) further demonstrated that in ovo administration of vitamin C improved hatchability to 93.3% compared to 91% in the control group, reinforcing our findings.

The beneficial effects of in ovo vitamin C supplementation are particularly evident during the late stages of embryonic development, notably on days 15 or 17 of incubation. This targeted injection strategy has been shown to reduce embryonic mortality, enhance antioxidant activity, and strengthen immune responses. Specifically, vitamin C mitigates oxidative stress and hypoxia (oxygen deficiency), thereby creating a more favorable physiological environment for optimal embryonic development, ultimately improving hatchability outcomes [13].

Furthermore, Khaligh et al. (2018) investigated the impact of in ovo ascorbic acid administration on hatchability and concluded that in ovo injection significantly enhanced hatchability rates in treated eggs compared to non-injected controls [5]. These findings further underscore the potential of in ovo vitamin C supplementation as a practical and effective approach for improving hatchability and overall chick quality in commercial poultry production.

Nowaczewski et al. [6] reported that in ovo administration of 3 mg and 6 mg of vitamin C into the air sac of broiler eggs on days 13, 15, and 17 of incubation had no significant effect on hatchability. However, in ovo feeding of 4 mg and 8 mg of vitamin C into the air sac of Peking duck eggs on day 20 of incubation significantly improved hatchability, which is consistent with our findings.

Similarly, a study conducted by Zhu et al. (2019) indicated that in ovo injection of vitamin C did not lead to an increase in chick body weight at hatch, aligning with our results [13]. In contrast, Salim et al. [7] investigated the effects of in ovo administration of vitamin E and ascorbic acid on day 12 of incubation in Muscovy ducks. Their findings revealed that injection of either vitamin E or vitamin C resulted in a higher hatchling weight compared to the non-injected control group, which contradicts our findings.

Several studies have explored the impact of in ovo vitamin C injection on hatchability and antioxidant enzyme activity, emphasizing the critical role of injection timing based on research objectives. Some studies have focused on day 15 of embryonic development, particularly to examine its effects on antioxidant enzyme activity and protection against oxidative stress. This time point is recommended due to the increased metabolic activity of the embryo and the maturation of antioxidant systems. Other studies suggest that injecting vitamin C on day 11 can enhance antioxidant performance and post-hatch chick quality. This timing is often considered optimal for broader effects, as the embryo at this stage is highly receptive to nutrient absorption and undergoing critical physiological development. Selecting day 15 for injection—when focusing on antioxidant enzyme activity and metabolic adaptations—appears to be a strategically effective approach [11].

Moreover, in ovo supplementation of vitamin C significantly influenced glutathione peroxidase enzyme concentration in hatchlings. Specifically, injecting 3 mg of vitamin C per egg resulted in an increase in antioxidant enzyme activity. Non-enzymatic antioxidants such as vitamin C and plant-derived compounds have been widely used to protect tissues from superoxide radicals, enhancing cellular survival by stimulating endogenous antioxidant enzyme systems [4].

Antioxidants such as vitamin C, vitamin E, folic acid, zinc, and chromium are naturally present in the body. Additionally, antioxidant enzymes such as catalase, superoxide dismutase (SOD), and glutathione peroxidase (GPX) play a vital role in protecting cells from oxidative damage caused by reactive oxygen species (ROS). These ROS are naturally produced at the cellular level as part of physiological functions. However, studies have shown that elevated environmental temperatures lead to an increase in free radicals and oxygen species in body fluids and tissues.

While low levels of ROS are essential for various biochemical processes, their excessive accumulation—resulting from overproduction or weakened antioxidant defenses—can damage biological macromolecules and disrupt normal cellular metabolism. The body possesses defense mechanisms that protect cells against oxidative stress and regulate ROS levels to prevent excessive buildup. Antioxidant nutrients and enzymatic defense systems are the primary safeguards against all forms of oxidative stress [4].

Our study's findings do not align with those of study [10], which reported that vitamin C injection enhances the activity of SOD and CAT enzymes. Instead, our results indicate that vitamin C may play a crucial role in counteracting oxidative stress by increasing the activity of antioxidant enzymes such as GPX and total antioxidant

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capacity (TAC). These findings suggest that vitamin C supplementation can enhance antioxidant enzyme activity. Furthermore, the administration of vitamin C may help reduce oxidative stress and improve broiler production efficiency in the poultry industry.

A study conducted by Zhou et al. in 2019 found that TAC activity significantly increased in broilers receiving vitamin C, which aligns with our findings. However, no significant differences were observed in GSH-PX and SOD activities or MDA content [13].

The antioxidant defense system is primarily assessed by measuring GPX, SOD, CAT, TAC, and MDA levels, all of which are essential components of the body's oxidative defense system. Based on our results, TAC levels in the T1 group and GPX levels in both treatment groups showed significant differences compared to the control group. Regarding MDA levels, a significant difference was observed in the T1 and T2 groups compared to the control group.

Conclusion

The present study demonstrated that in ovo injection (T1 and T2) exerts beneficial effects on hatchability and antioxidant performance in broiler chickens. The hatchability rate in the T1 group was significantly higher than that in the control and T2 groups. Moreover, the activity of glutathione peroxidase (GPX) and total antioxidant capacity (TAC) in the T1 group was markedly elevated compared to the control group. Conversely, malondialdehyde (MDA) levels, an indicator of oxidative damage, were significantly lower in the T1 group than in the control and T2 groups. These findings suggest that in ovo injection can enhance antioxidant activity, thereby promoting growth and improving the overall health of broiler chickens

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Investigation of the Prevalence of Leptospiral Abortion in a Holstein Dairy Cattle Breeding Complex

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Abstract

Leptospirosis is a significant cause of abortion in dairy cattle herds and a zoonotic disease affecting both humans and animals. This retrospective study was conducted to investigate the epidemiology of leptospirosis and its reproductive consequences in a 760-head Holstein dairy herd over a two-year period. Results indicated that 406 animals (53%) exhibited clinical signs of the disease. The abortion rate attributed to leptospirosis was 14.7%. The microscopic agglutination test (MAT) was employed to assess seroprevalence. The highest prevalence of clinical signs was observed in dairy cows during their third lactation period (240 heads, 67%). Serum titers in affected animals ranged from 1:100 to 1:3200. The majority of cases and abortions occurred in the first year of the outbreak, with 357 animals (46.85%) showing clinical signs and 26 animals (4.6%) aborting, compared to 49 animals (12.06%) and 3 abortions (0.73%) in the second year among the 406 affected animals. All cows that aborted developed retained placenta. Given the high prevalence of leptospirosis and its consequences, implementing appropriate health policies, including vaccination, treatment of infected animals, and reduction of natural reservoir populations, is essential. Controlling this disease can mitigate economic losses and safeguard public health. Furthermore, educating at-risk individuals, particularly those with occupational exposure, is of paramount importance.

Keywords: Leptospirosis, abortion, dairy cattle, Holstein

Introduction

Abortion in dairy cattle represents a significant challenge in the livestock industry, potentially leading to reduced milk production and the loss of viable calves, thereby incurring considerable economic losses. The natural annual abortion rate in dairy herds typically ranges between 3 and 5 percent; however, when this rate exceeds 5 percent, it is deemed a serious issue warranting thorough investigation [1]. This phenomenon may be influenced by multiple factors, including infectious diseases, environmental conditions, and herd management practices, necessitating precise identification of these factors to mitigate losses.

Leptospirosis, a bacterial disease caused by pathogens of the genus Leptospira, is a well-documented cause of abortion in cattle. The disease is transmitted through contact with contaminated urine from infected animals or primary hosts such as rodents (particularly rats), dogs, or aborted materials from affected cattle, with transmission being particularly prevalent during warmer seasons (spring and summer) under suitable humidity conditions [2]. Beyond its impact on animal health, leptospirosis poses a significant risk to farm workers and veterinarians due to its zoonotic potential, underscoring the critical need for its control [3].

The pathogenic Leptospira species is Leptospira interrogans (L. I.), whereas the non-pathogenic species is Leptospira biflexa. Leptospira species are associated with specific hosts; for instance, cattle serve as the primary host for L. I. Hardjo, which is a major cause of abortion in cattle. However, cross-infection with other Leptospira serovars can occur. For example, L. I. Pomona, primarily hosted by pigs, is capable of infecting cattle.

Recent studies have identified multiple Leptospira serovars, including L. I. Hardjo, L. I. Pomona, and L. I. Grippotyphosa, as active in cattle populations, with abortion being the most prevalent clinical manifestation [4, 5]. This diversity underscores the importance of regional investigations into the prevalence of this infectious disease. Such studies can enhance understanding of the epidemiology of leptospirosis, mitigate economic losses in livestock production, and improve public health standards.

The objective of this study is to evaluate the occurrence of abortion due to leptospirosis in a large dairy cattle complex in northwestern Iran.

Materials and Methods

This study was conducted over a two-year period at a large dairy cattle complex with a capacity of 760 Holstein milking cows, located in the Moghan Plain, the northernmost region of Ardabil Province, Iran. Of the total population,

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178 head (23%) were primiparous heifers, and 582 head (77%) were multiparous dairy cows with more than one calving. Situated at an elevation of 40 meters above sea level, the region experiences varied climatic conditions throughout the year. Relative humidity, based on data from the Moghan Agricultural Research Unit, was recorded as follows: spring (75–80%), summer (50–60%), autumn (75–80%), and winter (80–90%). Monthly average temperatures during the leptospirosis outbreak were documented as: April (14–17°C), May (15–22°C), June (23–28°C), July (29–31°C), August (32–36°C), September (28–32°C), October (18–20°C), November (15–20°C), December (15–18°C), January (8–12°C), February (14–18°C), and March (13–15°C). These climatic conditions, particularly high humidity, may contribute to the prevalence of leptospirosis.

The complex comprised three dairy cattle breeding stations (each with a capacity of 1,000 head), one calf-rearing station, and one independent heifer-rearing station. The dairy stations were approximately 1,500 meters apart, while the calf and heifer stations were about 1,000 meters from each other. Each dairy station consisted of 10 separate pens, segregated based on milk production and cow status (lactating or dry). Facilities included a calving barn, a hospital, and a pen for bulls used for natural insemination. Each dairy station was equipped with two independent milking parlors, each with two 18-unit lines, allowing simultaneous milking of 36 cows. The parlors were designed as open sheds in a U-shape, and the entire dairy complex, spanning approximately 80 hectares, was enclosed by concrete block walls. Despite sanitary measures, the presence of rodents (e.g., rats and rabbits), potential vectors of Leptospira, was observed in the environment. Forage was sourced from the agro-industrial fields, and concentrate feed was obtained from a feed mill located 3 kilometers away. A fattening unit with an annual capacity of 12,000 male calves was situated 4 kilometers north of the dairy complex.

The first case of leptospirosis was identified in the summer of the first study year in a 6-month-old male calf, presenting with mucosal jaundice and hemoglobinuria. Initially mistaken for babesiosis, negative blood tests and persistent symptoms confirmed leptospirosis. By March of the same year, herd milk production declined significantly (approximately 25%), and mastitis cases increased, likely associated with the disease outbreak.

Leptospirosis-related abortions were investigated over the two years, typically occurring after the fifth month of gestation. Blood samples from aborting cows were sent to the Leptospirosis Laboratory at the Razi Institute (Hesarak, Karaj) for diagnostic confirmation. Serum samples were analyzed using the Microscopic Agglutination Test (MAT). Samples were transported on ice to the Razi Institute's Bacteriology Laboratory and tested with live Leptospira serovars, including L. interrogans serovars Hardjo, Pomona, Icterohaemorrhagiae, Canicola, and Grippotyphosa. A serum titer of ≤1:100 with 50% agglutination was considered positive, while titers below 1:100 were deemed suspicious. In this retrospective study, 29 aborting cows tested positive. Repeat blood sampling 2–3 weeks post-abortion indicated that abortions occurred post-infection, with positive titers present at the time of abortion.

Data were analyzed using SAS software (version 2008) with the GENMOD statistical method. Statistical significance was set at $P < 0.05$.

Results

In this retrospective study conducted at a Holstein dairy cattle facility, out of 760 dairy cows, 406 (53%) exhibited clinical signs of leptospirosis over a two-year period. Tables 1 and 2 illustrate the incidence of leptospirosis symptoms across different months of the year. According to Table 2, the highest prevalence of clinical signs was observed in cows during their third lactation period (240 cows, equivalent to 67%).

Results from the Microscopic Agglutination Test (MAT) on cows that experienced abortions due to leptospirosis confirmed infection with Leptospira interrogans serovar Hardjo. However, infections with other serovars, including L. interrogans Pomona, L. interrogans Canicola, L. interrogans Icterohaemorrhagiae, and L. interrogans Grippotyphosa, were also identified. Notably, some affected cows were concurrently infected with three serovars. Table 1 further details the frequency of various leptospirosis symptoms during the first year of the outbreak in the studied herd.

Overall, the abortion rate attributed to this zoonotic disease over the two-year outbreak was estimated at 14.7% among dairy cows displaying leptospirosis symptoms. Serum titers in affected cows ranged from 1:100 to 1:3200. Clinical signs were observed in 357 cows (46.85%) in the first year and 49 cows (6.12%) in the second year. The number of abortions recorded was 26 (6.4%) in the first year and 3 (0.73%) in the second year, out of the 406 cows (53.42%) exhibiting clinical signs. In total, the abortion rate due to leptospirosis was calculated at 7.4% (29 cows). All cows that aborted experienced retained placenta.

Table 3 presents the prevalence of abortions and leptospirosis symptoms across different lactation periods over the two-year study.

The findings of this retrospective analysis indicate that cows in their third or higher lactation period exhibited the highest abortion rates due to leptospirosis. Additionally, all cows that aborted were affected by retained placenta.

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Table 1 – Frequency Distribution of Leptospirosis Symptom Incidence in the First Year of the Leptospirosis Outbreak

Month	Lactation Period	Total (%)
	First (%)	Second (%)
March-April	19 (5)	33 (9)
April-May	5 (1)	22 (6)
May-June	-	-
June-July	2 (0.56)	3 (1)
July-August	1 (0.28)	-
August-September	-	2 (0.56)
September-October	2 (0.56)	-
October-November	2 (0.56)	2 (0.56)
November-December	5 (1)	2 (0.56)
December-January	2 (0.56)	2 (0.56)
January-February	8 (2)	4 (1)
February-March	1 (0.28)	-
Total	47 (13)	70 (20)

Note: Percentages are calculated relative to the total number of cases (357). The symbol "-" indicates no recorded cases for the specified period.

Table 2: Frequency Distribution of Livestock Exhibiting Leptospirosis Symptoms in the Second Year of the Disease Outbreak

Month	Lactation Period	Total (%)
	First (%)	Second (%)
March-April	2 (4)	2 (4)
April-May	8 (16)	2 (4)
May-June	3 (6)	-
June-July	2 (4)	-
July-August	-	-
August-September	2 (4)	-
September-October	3 (6)	1 (2)
October-November	3 (6)	-
November-December	1 (2)	-
December-January	-	-
January-February	3 (6)	-
February-March	2 (4)	-
Total	29 (59)	5 (10)

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Table 3: Prevalence of Leptospiral Abortion in Different Lactation Periods During a Leptospirosis Outbreak in a Dairy Cattle Breeding Unit in Ardabil Province, Iran

Year of Disease Outbreak	Lactation Period						Total (%)	
	1 (%)		2 (%)		3< (%)			
	Symptoms (%)	Abortion (%)	Symptoms (%)	Abortion (%)	Symptoms (%)	Abortion (%)	Symptoms (%)	Abortion (%)
1	47 (11.75)	4 (13.79)	70 (17.24)	9 (31.03)	240 (59.11)	13 (44.82)	357 (87.93)^A	26 (6.4)^B
2	29 (7.14)	1 (3.44)	5 (1.23)	1 (3.44)	15 (3.69)	1 (3.44)	49 (12.06)	3 (0.73)^A
Total	76 (18.71)^{a,b}	5 (17.24)^b	75 (18.47)^b	10 (34.48)^b	255 (62.8)^a	14 (48.27)^a	406	29 (7.4)

*a, b: Values within the same row bearing different superscript letters (a, b) are significantly different (P<0.05).
*A, B: Values within the same row bearing different superscript letters (A, B) are significantly different (P<0.05).

Discussion

The present investigation revealed that the incidence of abortion during the first year of the pandemic was substantially higher than in the second year. The abortion rate was reported as 6.4% (26 cases) in the first year, compared to 0.73% (3 cases) in the second year. Analytical findings indicate that in the first year, livestock with three or more parturitions experienced the highest impact, with an abortion incidence rate of 44.82%, whereas this rate decreased in animals with fewer parturitions. This discrepancy is likely associated with diminished immunity in livestock with higher parity during the initial months of the pandemic.

The results further demonstrated that the prevalence of leptospirosis infection in cattle with three or more parturitions, two parturitions, and one parturition was 67% (240 cases), 20% (70 cases), and 13% (47 cases), respectively, with at least one clinical symptom of leptospirosis observed. Implementation of sanitary and therapeutic protocols, including streptomycin treatment, vaccination against leptospirosis, rodent and canine control, and improved environmental hygiene, led to a significant reduction in symptoms during the second year. However, in contrast to the first year, cattle with a single parturition exhibited the highest incidence of symptoms in the second year. This finding may be linked to the introduction of replacement heifers into the herd, which, due to their greater susceptibility to leptospirosis, manifested more severe symptoms.

Leptospirosis, a zoonotic disease, is particularly prevalent in tropical regions [6]. The causative agent is a spirochete bacterium of the genus Leptospira, classified into over 20 serogroups and 200 serovars. Transmission occurs directly through urine, uterine secretions, mating, milk, or colostrum of infected animals, or indirectly via contaminated environments facilitated by domestic and wild vectors. Currently, Leptospira is categorized into 10 pathogenic species, including L. interrogans and L. borgpetersenii, as well as intermediate and saprophytic species [7]. The disease is globally distributed, with reports of livestock infections documented in Iran [8].

Each serovar tends to proliferate in a specific mammalian species as its reservoir host, where the disease persists endemically with direct transmission among individuals of the same species [9]. In reservoir hosts, symptoms are typically mild, whereas in non-reservoir hosts, infections may manifest acutely. In fetuses, placental inflammation and the transplacental passage of Leptospira result in varied outcomes depending on the gestation stage, including abortion, stillbirth, birth of weak calves, or antibody production and fetal survival. Leptospira persists in uterine secretions for up to 8 days post-parturition and in the uterus of pregnant animals for up to 150 days [10].

Leptospirosis-induced abortions typically occur between days 45 and 260 of gestation, most commonly observed 6 to 12 weeks following the acute phase of the disease, with peak incidence in the sixth month [11]. This complication may occur without distinct clinical symptoms. Infection with incompatible serovars (e.g., Pomona, Canicola, Copenhageni, Icterohaemorrhagiae, and Grippotyphosa) can induce acute febrile illness with body temperatures of 40°C or higher, hemoglobinuria, jaundice, anorexia, and even leptospiral mastitis. Calf mortality and isolated or widespread abortions have also been reported.

The implementation of sanitary measures, such as isolating infected animals, controlling rodents, managing contaminated water sources, and installing fencing, contributed to reducing disease transmission from other host species. The serological microagglutination test (MAT), widely employed in epidemiological studies, detects Leptospira antibodies 5 to 7 days after symptom onset [12]. In this study, MAT results at the time of clinical symptom onset indicated a high level of seropositivity, with all aborting animals testing positive for L. interrogans serovar Hardjo.

Statistically, the incidence of abortion in animals with three or more parturitions was significantly higher ($P<0.05$) than in other groups. Rodents, as the primary disease reservoir, play a critical role in transmitting the infection to domestic livestock and humans [9]. Symptoms of leptospirosis in cattle include reproductive disorders, reduced milk production, and abortion (with rates ranging from 5 to 40%) [7]. However, some studies have not identified cattle as the primary reservoir of the disease, citing them solely as a contributing factor to abortion [13].

In the present study, the Microscopic Agglutination Test (MAT) revealed that cattle were infected with five Leptospira serovars (Pomona, Grippotyphosa, Icterohaemorrhagiae, Hardjo, and Canicola); however, L. interrogans serovar Hardjo was identified as the primary agent responsible for abortion. This finding contrasts with other research conducted in Iran, such as the study by Abdollahpour et al. (2012) [14], which reported serovar Pomona as the predominant cause of abortion in dairy farms surrounding Tabriz. The overall results of this investigation suggest that the implementation of effective control measures, combined with the utilization of synergistic diagnostic approaches (such as MAT and PCR), can significantly contribute to mitigating the economic losses attributable to leptospirosis and facilitate improved disease management within dairy herds.

Conclusion

The prevalence of leptospirosis and the subsequent manifestation of clinical signs associated with the disease are notably high. However, the incidence of abortion, typically observed in chronic infections, remains relatively low when compared to the overall disease frequency. Serovars Pomona and Hardjo are implicated as potential causative agents of abortion in cattle. Dairy cattle are susceptible to infection by both host-specific and non-host-specific Leptospira serovars. Disease containment can be achieved through the adoption of intensive control strategies, including the reduction of reservoir host populations, immunization of livestock, and therapeutic intervention for clinically affected cattle. Effective control of leptospirosis results in a demonstrable reduction in economic damages within dairy herds. Furthermore, given that leptospirosis constitutes a significant occupational hazard, mandatory educational programs for individuals at risk of exposure to the pathogen are deemed essential.

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Investigating the impact of the tendency towards a sustainable environmental market orientation on the company's export performance through the mediation of resources, green export capacities and green marketing strategy
(Case study: Pars Khazar Company)

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Abstract
Exports play an important role in the economic development of countries. According to the results of the analysis of the situation of forty-one countries between 2012 and 2024 by the World Bank, the economic performance of countries with extroverted economies has been almost better and superior to introverted economies in all aspects. The present study investigated the effect of the orientation towards a sustainable environmental market on the export performance of the company through the mediation of resources, green export capacities and green marketing strategy in Pars Khazar Company. The present study is applied in terms of purpose and descriptive-survey in terms of method. The sample size was 150 managers and experts of Pars Khazar Company Group in Tehran, which was selected by simple random sampling and based on the Cochran formula. The analysis method of the present study examined the effect between the hypotheses using the Kolmogorov-Smirnov test, factor analysis test and structural equations with LISREL software. According to the results, the strength of the calculated relationship in all variables is considered an acceptable value. Also, the Ney test statistic was greater than the critical t-value at the 5% error level, i.e. 1.96, indicating that the observed correlation is significant. Therefore, it was confirmed with 95% confidence that the orientation towards a sustainable environmental market has a significant effect on the company's export performance through the mediation of resources, green export capacities and green marketing strategy in Pars Khazar Company.
Keywords: The tendency towards sustainable environmental market - Company export performance - Green export capacities - Green marketing strategy - Pars Khazar Company

Introduction
Exports play an important role in the economic development of countries. According to the results of the analysis of the situation of forty-one countries between 2012 and 2024 by the World Bank, the economic performance of countries with extroverted economies has been better and superior to introverted economies in almost all aspects [1]. Leonidou, Katsikias and Sami (2018) have classified the factors affecting successful export performance into five groups. These factors are: managerial factors (personal, experience, attitude and perception, behavioral and characteristics related to decision-makers of exporting companies), organizational (elements related to the characteristics, operations, resources and objectives of the organization), environmental factors (factors that shape the operating environment and macro-environment of exporting companies), targeting of export markets (identifying and selecting international target markets), marketing mix variables (product strategy, price, distribution and promotion). In a more recent study, Wilkinson Bros (2019) examined the export experiences and performance of small and medium-sized enterprises and examined the impact of using export promotion services on export barrier variables, human resources, and export performance. Despite the importance of exports, national policies on the movement of goods between countries have always been inconsistent. Governments encourage exports by providing subsidies and indirect protections. Indirect export support includes tax breaks and extensive government support programs for export training and development. At the firm level, exporting creates growth and development opportunities for companies. By expanding access to foreign markets, the company can achieve a higher level of production. Exporting creates market diversification opportunities for companies. In addition, it allows the company to take advantage of different growth rates in different markets and reduces the company's dependence on a specific market. Exporting provides the company with the opportunity to learn from competition and allows the company to gradually achieve the ability to survive in unfamiliar and alien environments [2]. Governments usually support the export activities of companies by using incentives and support programs due to the importance of exports, which are known as export promotion/encouragement programs. The aim of these services and efforts is to help companies operating in an economic territory to start or continue international activities (exports) and reduce the risk of doing so. One group of these programs provides trade and export information to companies, others are provided with the aim of creating or increasing the incentive for companies to export, and an important part also includes financial and operational support (such as export financing,

export insurance, export transportation training, export marketing, conducting foreign trade missions, establishing business relationships with foreign traders). Also, significant amounts of money are spent on export promotion programs annually in Iran. In addition, a specific institutional framework has been formed in the country to support exports, including the Trade Development Organization, the Institute of Trade Studies and Research, the Export Guarantee Fund, the Export Development Bank, and the International Exhibitions Company. However, although the export promotion strategy has been on the agenda of Iranian governments for several decades as one of the main strategies in line with the macro-economic growth policy and programs, and numerous activities have been carried out in this regard, according to the results of the studies, despite having high export potential, Iran has a small share of international markets, and although Iran's exports have been on an upward trend since the formulation of the Third Development Plan, there is still a long way to go. In addition, the composition of the country's export goods also needs to be reformed and improved [3]. Incentive programs have categorized exports into three groups: financial incentive programs (including tax exemptions, export loans, import substitution permits, and export insurance), technical assistance programs (marketing promotion in target countries, import assistance to exporters, and export transportation protections), and other incentives (bureaucratic reform and export awards). Iran's exports are significantly lower than those of developed and peer countries [4]. Export performance shows the extent to which a company achieves its goals, both economic and strategic, for exporting products to foreign markets (Mavrogiannis et al., 2018). Export marketing experts believe that identifying the determinants of export performance in order to increase export performance and achieve a desired level of it is an important and vital issue for companies in today's competitive market. In addition, the factors affecting the export performance of companies are often faced with several theoretical perspectives due to the globalization of markets and the increasing competition of foreign companies, and many different variables have been introduced by different researchers in the field of factors affecting export performance. If these perspectives are considered complementary, it enables the manager to understand the multidimensional structure [5]. This issue has been addressed to some extent in the home appliance industry. Numerous areas and factors can affect export performance in Pars Khazar Company due to the expansion of this industry and its connection with many economic and social sectors, etc. at the national level and also in countries that use Iranian products. It is clear that the use of export incentive programs in the home appliance industry leads to the manufacture of products with higher quality compared to other competitors and the expansion of exports in this industry, which in turn causes changes and transformations in the country's economy. Export incentive programs have an indirect effect on export sales. Companies must do more than just supply suitable products. Government and incentive support should be given a good position and more sales in exports by using export promotion programs, including: Extensive advertising. Marketing is one of the major tools of promotion programs that cause export growth. Many companies are unable to do so due to lack of work experience and limited resources and information regarding export sales. Here, the development of export promotion programs by the government and institutions is essential for the country's economy. Therefore, the main question is: What is the impact of the trend towards a sustainable environmental market on the company's export performance through the mediation of resources, green export capacities, and green marketing strategy in Pars Khazar Company? It is essential to examine the determinants and influences of export performance to understand the relationship between export promotion programs and export performance. Abi and Slater (2018) divide the factors affecting export performance into external and internal factors. According to their model, export performance is influenced by three groups of internal variables: firm characteristics (such as firm size and management's attitude towards exports), firm capabilities (such as marketing knowledge and technology), and international marketing strategy (such as target markets, entry method, and marketing mix adaptation to target markets). In addition, they emphasize that a firm's export performance is also influenced by external variables. Export and export performance are considered as a way to analyze the relationship between incentive programs. The behavioral theory of the firm deals with the issue of "how firms organize and process information when faced with the decision-making process". Within the framework of this theory, questions such as "Why do firms export?", "Why do they refrain from continuing?", "Why do they not achieve their export goals?" can be raised and analyzed. Within the framework of behavioral theory, it can be said that the initiation and continuation of exports is due to export incentives and its cessation or lack of development is due to the effect of real or perceived barriers to exports.[2]

As a result, the industry has sufficient motivation for quantitative and qualitative growth. Therefore, the present study examines the effect of the orientation towards a sustainable environmental market on the company's export performance through the mediation of resources, green export capacities and green marketing strategy in Pars Khazar Company. Therefore, considering the importance of the topic, the second part of the article includes a review of the literature on the subject and the statement of the research hypotheses. In the third part, the research method is described. Data analysis and the results obtained are described in the fourth part. Also, in the fifth part, the research results are presented.

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2. A review of the research literature

The tendency towards a sustainable environmental market

Orientation refers to "a set of activities developed by organizations to continuously monitor and respond to market changes such as customer preferences, faster technological growth, and the growth of the competitive environment" [6].

Green Marketing Strategy

According to Markides (2018), green marketing strategy is a completely different way of competing in an industry that emerges by breaking the rules of the game and thinking in new ways. A key element, according to him, is: "reconceptualizing what business is about, and what leads to a different way of playing the game correctly in the industry"[8].

Green Export Capacities

Export capacities refer to the implementation of activities in the business environment that direct the flow of goods and services from the producer to the consumer[9].

Export performance

Export performance refers to the extent to which a company achieves its goals in the process of exporting a product to international markets [10].

Rahmani (2023), in a study titled "Identifying and prioritizing export barriers and providing solutions for developing exports of small and medium-sized industries in West Azerbaijan Province" investigated and identified export barriers in West Azerbaijan Province industries. According to his results, the most important factors affecting the export of food industries in West Azerbaijan Province include export laws, lack of marketing programs, lack of specialized training in the field of export, obtaining health permits, the banking system, and the cultural level of the society in relation to the export category.

After reviewing the research results, he concluded that there is a need for measures by managers of small and medium-sized companies and the government to further develop the province's exports, especially in the field of food industries. Among the most important measures that should be given special attention by managers of organizations and policymakers are the implementation of marketing programs and the development of appropriate strategies for marketing the province's food products in target markets, adjusting and amending export laws and regulations, revising the banking system in order to grant easier and more targeted bank loans and financial transactions, and taking the necessary measures to obtain health permits. Therefore, the first hypothesis is:

H1 - The tendency towards a sustainable environmental market has a significant effect on resources in Pars Khazar Company.

Ebrahimi (2022), in a study titled "Measuring the Performance Status of Stone Exports", examined the obstacles and factors of weakness in Lorestan stone export based on Porter's Diamond Model. He concluded that according to Porter's Diamond Model, the six effective factors examined include internal factors, domestic demand conditions, related and supporting industries, strategy, structure and competition, the role of the government, and unforeseen events in the weakness of Lorestan's stone exports. According to the results of the analysis of this study, factors related to the role of the government have the greatest impact and factors related to domestic demand conditions have the least impact on the weakness of Lorestan's stone exports. Therefore, the second hypothesis is:

H2- The tendency towards a sustainable environmental market has a significant effect on green export capacities in Pars Khazar Company.

Sadeghi (2022), in a study titled "Presenting a model of the main factors of success in exports from the perspective of exporters in Iran", examined the effective and influential factors in the success of exports. According to the analysis of the results, the most important factors affecting the increase in exports from the perspective of exporters in terms of importance and impact, respectively, are the environmental factor in the order of variables (laws and regulations, culture, special communications, technology, political factors), the product side factor in the order of variables (warranty and after-sales service, distribution channels, product quality, brand, design and packaging), the individual factor in the order of variables (public relations, export knowledge, education, work experience) and finally the economic factor in the order of variables (export marketing, government subsidies, export pricing, export markets).

He ultimately concluded that reaching broad markets and commercial success requires moving towards an open economy, employing marketing strategies, and a thoughtful look at the needs and desires of different customers in different markets. Therefore, the third hypothesis is:

H3- The tendency towards a sustainable environmental market has a significant impact on the green marketing strategy of Pars Khazar Company.

Saeedi and Ahmadi (2019) in their study of the "relationship between export support and export performance of oil companies" concluded that export support has a direct effect on improving export performance, but this effect is not significant, because this positive effect is moderated by the negative effect of price adjustment to foreign market conditions. Therefore, the fourth hypothesis is:

H4- Resources have a significant impact on the company's export performance in Pars Khazar Company.

In a study titled "Investigating Non-Oil Export Barriers in Khuzestan Province Using Factor Analysis," Darisavi Bahmanshir (2019) examined the barriers to non-oil exports in Khuzestan Province. He identified several factors as the most important barriers to non-oil exports. These factors include: lack of knowledge of foreign consumer markets, lack of familiarity with new trade practices, poor quality of goods, problems with transportation of goods, pricing issues and financial and exchange problems, poor packaging, government bureaucracy, problems related to training and encouraging exporters, customs and export customs problems, and changes in export and import regulations.

Regarding the lack of familiarity with new business practices, it can be pointed out that the use of new business technologies in export firms, behavioral variables such as the level of human resource skills of firms, the volume of investment in research and development, and wage rates are effective in the acceptance of e-business by firms. Therefore, the fifth hypothesis is:

H5- Green export capacities have a significant impact on the company's export performance in Pars Khazar Company.

Zinkota (2023) describes in a process model that export promotion programs only indirectly affect export performance. These programs are considered as tools to increase organizational and managerial resources, competencies, and capabilities. Researchers point out that export promotion programs improve the export capabilities of firms, and ultimately improve the chances of firms succeeding in foreign markets. Therefore, the sixth hypothesis is:

H6- Green marketing strategy has a significant impact on the company's export performance in Pars Khazar Company.

Bianchi and Matthews (2022) investigated the impact of export marketing on economic market growth. According to previous studies, export activities have a positive impact on the export activities of firms in developed markets. However, the present study was conducted with the aim of investigating the impact of export marketing on the export performance of firms in emerging markets. According to data from 204 exporting firms in Chile, the findings show that export marketing capacities have a positive impact on the availability of export information, which in turn affects the development of business network relationships and export market growth. Therefore, the seventh hypothesis is:

H7- The tendency towards a sustainable environmental market has a significant impact on the company's export performance through the mediation of resources in Pars Khazar Company.

Guitom Tsefem (2019) concludes in his research that internal export barriers in companies are related to insufficient resources for export marketing, issues related to achieving quality standards and creating a suitable design and image for the foreign market, and issues related to weak organization and lack of qualified personnel to manage export activities, financial inability and lack of sufficient information about foreign markets, and external barriers include completely different performance of foreign customers, unfamiliarity with work procedures and activities, tariff barriers and import laws of other countries, competitive forces, inflation rates, and limited supply of some currencies. Therefore, the eighth hypothesis is:

H8- The tendency towards a sustainable environmental market has a significant impact on the company's export performance through the mediation of green export capacities in Pars Khazar Company.

Abi and Slater (2021) divide the factors affecting export performance into external and internal factors. According to the model of these two researchers, export performance is influenced by three groups of internal variables, namely company characteristics (such as company size and management's attitude towards exports (company capabilities such as marketing knowledge and technology) and international marketing strategy (such as target markets, entry method and marketing mix adaptation to target markets). Therefore, the ninth hypothesis is:

H9- The tendency towards a sustainable environmental market has a significant effect on the company's export performance through the mediation of green marketing strategy in Pars Khazar Company.
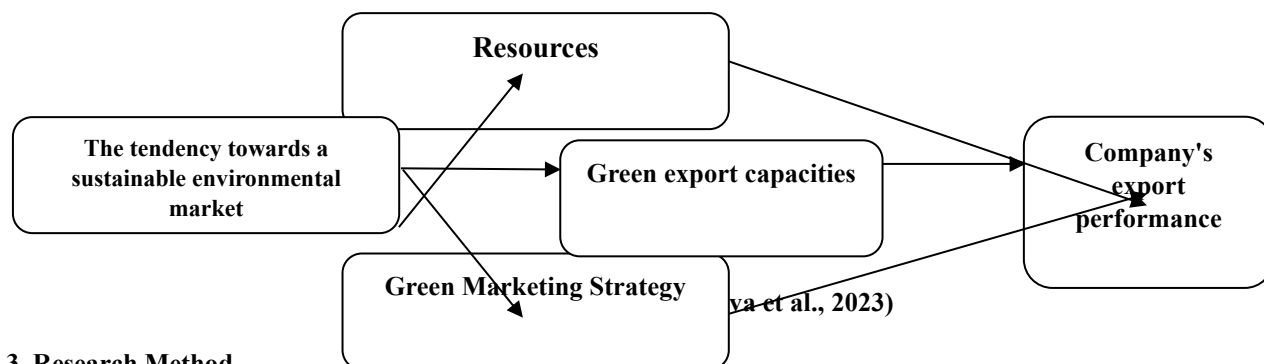
2.1. Conceptual model

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(Silva et al., 2023)

3. Research Method

3-1 Measurement Tools

A questionnaire using a five-option Likert scale was designed to conduct the research. The questions in the questionnaire consist of two parts. The first part of the questionnaire is designed to examine the demographic characteristics of the respondents. These questions are designed to classify the respondents in terms of gender, age, education, duration of use, city. The second part of the questionnaire includes a standardized questionnaire. In order to examine the reliability of this research, the researcher has used the Cronbach's alpha coefficient method, which is one of the internal correlation methods in the reliability of a questionnaire. The reliability of the independent variable is .793 and all dimensions are .824.

Table 1: Questionnaire questions

Questionnaire source	Question Classification	Dimensions	
Silva et al. (2023)	Questions 1 to 4	The tendency towards a sustainable environmental market	**Research variables**
Silva et al. (2023)	Questions 5 to 8	Resources	
Silva et al. (2023)	Questions 9 to 12	Green marketing strategy	
Silva et al. (2023)	Questions 13 to 16	Green export capabilities	
Silva et al. (2023)	Questions 25 to 28	Company export performance	

3-2 Sampling and Data Collection Method

Simple random sampling method has been used in this research. This research is applied in terms of purpose and descriptive method has been used in terms of data collection. Using Cochran formula, the number of sample members is 150 people selected from all managers and experts of Pars Khazar Company Group in Tehran.

3-2-1- Analysis Method

Data analysis and analysis using SPSS software is presented in this section. First, descriptive statistics (frequency table, bar chart) are used to summarize and describe the data of demographic factors, and in the second stage, structural equations are used with LISREL software to test the hypotheses according to hypotheses 1 to 9.

Research findings

Table 2: Gender composition of sample members

Cumulative Frequency Percentage	Frequency percentage	Frequency	
64	64	96	**Male**
100	36	54	**Female**
	100	150	**General**

Table 3: Educational composition of sample members

Cumulative Frequency Percentage	Frequency percentage	Frequency	
50	50	75	**Bachelor**
40	40	60	**Master**
100	10	15	**Postgraduate**
	100	150	**Total**

Table 5: Data normality test

Significance Level (Sig.)	Test result	Variables
0.263	The data distribution is normal	Tendency towards environmentally sustainable market
290/0	The data distribution is normal	Resources
342/0	The data distribution is normal	Green marketing strategy
233/0	The data distribution is normal	Green export capabilities
230/0	The data distribution is normal	Company export performance

Table 6: Path coefficients of the relationship between the structure and their corresponding components

Impact factors	T-statistic	Hypotheses
0.70	**9.52**	The tendency towards a sustainable environmental market has a significant effect on resources in Pars Khazar Company.
0.65	**8.15**	The tendency towards a sustainable environmental market has a significant effect on green export capacities in Pars Khazar Company.
0.78	**10.39**	The tendency towards a sustainable environmental market has a significant effect on green marketing strategy in Pars Khazar Company.
0.61	**5.46**	Resources have a significant effect on the export performance of the company in Pars Khazar Company.
0.53	**6.31**	Green export capacities have a significant effect on the export performance of the company in Pars Khazar Company.
0.69	**7.86**	Green marketing strategy has a significant effect on the export performance of the company in Pars Khazar Company.
0.73	**8.11**	The tendency towards a sustainable environmental market has a significant effect on the export performance of the company through the mediation of resources in Pars Khazar Company.
0.77	**8.29**	The tendency towards a sustainable environmental market has a significant effect on the export performance of the company through the mediation of green export capacities in Pars Khazar Company.
0.79	**6.59**	The tendency towards a sustainable environmental market has a significant effect on the export performance of the company through the mediation of green marketing strategy in Pars Khazar Company.

Table 7: Results of the Sobel test of the first main hypothesis

Z-value of green export capacities	Z-value Value of Resources	Research Hypotheses
3.679	3.579	The tendency towards a sustainable environmental market on the export performance of the company
Z-value Value of resources	Z-value Value of Green Marketing Strategy	Research Hypotheses
3.468	3.517	The tendency towards a sustainable environmental market on the export performance of the company

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This hypothesis is rejected with the p-value = 0.000, as well as the standardized t-value and the cut-off point for their significance at the 99% confidence level, and the statistical hypothesis H0 is significant in the target population. Therefore, all research hypotheses were confirmed.

The factor analysis method and structural equations with LISREL software were used in the present study, which has two variables: the path coefficient and the t-statistic, such that the value of the t-statistic in the effect of the independent variable on the dependent is a criterion for rejecting or accepting the effect of the independent variable on the dependent. If the absolute value of the obtained statistic is higher than 1.96, it indicates a significant effect of the independent variable on the dependent variable. In fact, the value of the statistic is obtained from the ratio of the path coefficient to the standard deviation of the coefficient and follows the t-distribution, and since the hypotheses in the present study are tested at a 95% confidence level, and the standard value of the t-statistic at a 95% confidence level is 1.96, the value of the statistic obtained from the path analysis is compared with the value of 1.96, and if this value is higher than 1.96, it indicates that the value of the statistic is in the rejection region of the null hypothesis, and the null hypothesis of the test of the coefficient's non-significance is rejected with 95% confidence. Therefore, all hypotheses were confirmed with 95% confidence. For hypotheses 1 to 9, factor analysis and structural equations were used with LISREL software. As can be seen in the table above, the value of the pleasant experience variable in all research hypotheses is further from zero, indicating a stronger effect of the mediating variable in the hypotheses. The results of the present study are consistent with the findings of Rahmani (2023), Ebrahimi (2022), Sadeghi (2021), Saeedi (2020), Zinkota (2023), Bianchi (2022), Tezfam (2019), Abb and Slater (2021).

5. Results

In this study, environmental concerns and sustainability issues are increasingly becoming part of the lives of people and companies. The obvious negative consequences of human actions on the environment are leading consumers, as well as companies, to adopt environmentally conscious behaviors [11]. In what concerns companies, this means changing practices and integrating environmental aspects into the way they think and do business (e.g., Vardarajan, 2014). However, only a few studies have devoted time to analyzing the green aspects of exports (e.g., Leonidou et al., 2013a; Martin-Tapiá et al., 2010). The present study aims to understand the impact of the orientation towards a sustainable environmental market on the resources and capabilities associated with green exports, and their impact on the marketing strategy of environmentally friendly exports. The model also examines the impact of environmentally friendly export marketing strategy on export performance. According to the results, the orientation towards a sustainable environmental market positively affects the resources and capabilities related to green exports. Therefore, companies that incorporate sustainability into their market orientation and have a culture that advocates sustainable principles, standards and behaviors tend to choose green resources and capabilities. In addition, green export-related capabilities contribute to the environmentally friendly export marketing strategy, the resources related to green exports. The resources related to green exports indirectly affect the environmentally friendly export marketing strategy. Such a strategy is implemented by deploying resources in capabilities, not through resources. Finally, the environmentally friendly export marketing strategy positively affects the export performance of the company, which confirms the results of previous studies in this field [12]. These findings suggest that this study will be very useful. First, this study combines the literature on marketing, sustainability, exports, and firms, and proposes an integrated model that studies organizational factors - marketing strategy - performance. Second, this study analyzes the tendency towards a sustainable environmental market, and in this regard, we find that market-oriented firms that consider sustainability issues tend to support green resources and capabilities. Furthermore, while the development of capabilities provides export marketing strategy, the possession of resources by itself plays a minor role in this area.

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(Electromagnetic Wave Absorption Properties of Mesoporous Silica-Polyacrylic Acid-Polypyrrole Composites in the Ku-Band

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ABSTRACT

Composites of mesoporous silica and polypyrrole (PPy) were prepared using different techniques, utilizing in-situ polymerization on the surface of core-shell structured nanoparticles (NPs). This study introduces a novel approach for coating the nanoparticles with polyacrylic acid (PAA) in an aqueous medium. The combination of powders with outstanding electromagnetic wave absorption (EMA) properties and resins is a crucial strategy for developing electromagnetic wave (EMW) shielding composites. However, the high cost, low efficiency, and complex synthesis of these powders limit their application in composite materials. Furthermore, these composites require increased thickness to meet the electromagnetic wave absorption (EMA) standards. At a thickness of 1.7 mm, the composite effectively absorbs electromagnetic waves across the entire Ku band, and by adjusting the thickness, it achieves efficient absorption within the 12–18 GHz range. This study presents an innovative approach to creating cost-efficient, easily synthesized, and high-yield EMW absorbers, along with their potential use in absorber-based composite materials. The optimal microwave absorption was achieved at 12 GHz for PPy and at 15 GHz for MS-PAA-PPy, with a minimum reflection loss of -37.5 dB.

Keywords: PPy, wave absorption, Ku band, microwave, core-shell

INTRODUCTION

The rapid development of electronic devices, multi-band radar systems, and advanced microelectronic technologies has led to a significant rise in electromagnetic radiation, which poses risks to human health and threatens information security [1,2]. Therefore, the development of materials capable of absorbing electromagnetic waves (EMW) is of paramount importance. A wave-absorbing material is specifically engineered to capture EMW energy that strikes its surface and convert it into heat or other energy forms [3]. Currently, the most common industrial approach involves mixing wave-absorbing materials with resins, particularly epoxy resin (EP) [4]. In the past decade, microwave (MW) absorbing materials have gained significant attention due to their potential in mitigating electromagnetic interference. This is crucial for safeguarding human health and protecting electronic devices from the adverse effects of electromagnetic pollution, which has become increasingly prevalent with the widespread use of high-power electronic devices and advanced communication technologies. The growing demand for effective EMW shielding has driven extensive research into the development of these materials [5–10]. Designing an efficient, cost-effective, and high-performance electromagnetic wave (EMW) absorber is critically important. Conductive loss plays a key role in EMW absorption, where electromagnetic waves penetrate the material and are converted into electric currents upon interaction with conductive components, eventually dissipating as Joule heat. Among the materials commonly used for conductive loss, graphene oxide (GO) stands out as a prominent example [11]. Among various conductive polymers (CPs), they stand out for their excellent stability, lightweight nature, flexibility, and ease of processing. Polypyrrole (PPy) is a notable conductive polymer, distinguished by its relatively low redox potential compared to other CPs. This unique property allows for its straightforward synthesis through oxidative polymerization, making it easily accessible for various applications. Due to these characteristics, PPy has garnered significant attention in fields requiring efficient conductivity and stability [12]. Moreover, the exceptional flexibility and high conductivity of PPy make it an ideal material for producing resin-based composite absorbers. However, without proper treatment, untreated PPy tends to aggregate into flaky or spherical forms due to the inherent characteristics of oxidative polymerization. This tendency to clump together can hinder its effectiveness in applications that require uniform dispersion and efficient performance. Therefore, controlling the morphology and dispersion of PPy is crucial for optimizing its properties in composite materials. The exceptionally high conductivity of pure PPy leads to the rapid absorption of electromagnetic waves (EMW) by the free electrons on its surface, forming a reflective layer. However, relying solely on pure PPy results in conduction loss, which limits its effectiveness as an

EMW absorber. As a result, significant efforts are being made to enhance the loss mechanisms of polypyrrole through advanced structural designs, particularly focusing on porous and hollow architectures to improve its absorption capabilities [13,14]. Nano-sized manganese ferrite and conductive polypyrrole composites exhibit a core-shell structure, which is formed through in-situ polymerization. This unique structure enhances the material's overall performance by combining the magnetic properties of manganese ferrite with the conductive capabilities of polypyrrole, leading to improved functionality in various applications. The core-shell configuration also provides better stability and efficiency in electromagnetic wave absorption [15]. The conductive and magnetic nanocomposites, featuring core-shell structures and various nanostructures, have been utilized for electromagnetic wave absorption applications. These advanced materials leverage the combination of magnetic properties and electrical conductivity to effectively absorb electromagnetic radiation, making them suitable for use in shielding and other protective technologies [16–18]. Mesoporous silica (MS), with its hollow structures, is a unique form of silica that finds widespread applications across various industries. It is commonly used in fields such as nano-reactors, catalysis, Pickering emulsions, energy storage, and resin reinforcement due to its versatile properties and ability to enhance material performance in these areas [19]. In this study, we focused on synthesizing a composite of MS by performing in-situ polymerization on the surface of all components, which were first coated with PAA. This paper presents an updated and expanded analysis of the microwave absorption properties within the frequency range of 12-18 GHz.

EXPERIMENTAL

Synthesis Of MS

Mesoporous silica (MS) was synthesized using a sol-gel method. Tetraethyl orthosilicate (TEOS) was used as the silica precursor and was mixed with a surfactant, cetyltrimethylammonium bromide (CTAB), to form micelles. The solution was then hydrolyzed and aged under controlled conditions. After aging, the product was dried and calcined at high temperatures to remove the surfactant and obtain the mesoporous structure.

Coating Of NPs With PAA (NPs-PAA)

Coating of nanoparticles with PAA (NPs-PAA) was carried out as follows: 0.5 g of nanoparticles (NPs) and 50 mL of a 5% (w/v) PAA solution were added to a 250 mL flask. The mixture was then sonicated for 15 minutes. Following this, the solution was stirred vigorously at 25°C for 24 hours. After the reaction, the mixture was filtered and washed with a 2% (v/v) acetic acid solution and acetone. The resulting NPs-PAA was obtained after vacuum drying the filtrate.

(PPy) Composite

The polypyrrole (PPy) composite, as a core-shell structure, was synthesized through template polymerization in the presence of DBSA as both surfactant and dopant, and Fe(NO3)3.9H2O as the oxidizing agent. 0.5 grams of DBSA were dissolved in distilled water and stirred vigorously for 20 minutes. Then, 0.287 grams of PAA-coated nanoparticles were added to the DBSA solution and stirred for approximately 1 hour. Next, 1 mL (0.015 mol) of freshly distilled pyrrole was added as the monomer to the suspension and stirred for 30 minutes. The PAA-coated nanoparticles were well dispersed in the PPy/DBSA mixture under ultrasonication for 2 hours. 12.12 grams (0.03 mol) of $Fe(NO_3)_3.9H_2O$, acting as the initiator, was dissolved in 30 mL of deionized water and slowly added dropwise to the reaction mixture while stirring. The polymerization proceeded for 6 hours. The resulting nanocomposite was obtained by filtration and washed with deionized water and acetone. The obtained dark powder contains [(MS)-PAA]-PPy and dried under vacuum for 24 h.

RESULTS AND DISCUSSION

Microwave Absorption Properties

To evaluate the electromagnetic wave (EMW) absorption performance of MS-PAA-PPy composites, the reflection loss (RL) curves for various samples were calculated and presented. Using transmission line theory, the RL values across the measured frequency range can be determined as follows:

$$RL = 20 \lg \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right|$$

(1)

$$Z_{in} = Z_0 \sqrt{\frac{\mu_r}{\varepsilon_r}} \tanh(j \frac{2\pi f d}{c} \sqrt{\mu_r \varepsilon_r})$$

(2)

In this equation, Z_{in} and Z_0 represent the impedance values of the absorber and air, respectively. Additionally, μr, εr, d, f, and c denote the complex permeability, complex permittivity, absorber thickness,

frequency, and the speed of light, respectively. The frequency range in which the RL value falls below -10 dB is considered the effective absorption bandwidth (EAB) of the absorber, as it signifies that over 90% of the incident electromagnetic waves are absorbed in this range. As illustrated, the pristine MS does not exhibit a distinct EAB within the tested frequency range, indicating that its intrinsic structural properties are not optimal for EMW absorption. This suggests the need for modifications to the material's structure to enhance its absorption efficiency across a broader frequency spectrum. Further optimization of the MS-PAA-PPy composites can potentially improve their EMW absorption capabilities, making them more suitable for electromagnetic shielding applications.

Microwave Absorbing Study

The microwave absorption properties of nanocomposites with a coating thickness of 1.7 mm were investigated using vector network analyzers in the frequency range of 12-18 GHz, which corresponds to the Ku-band. The results showed that the best microwave absorption was achieved within this frequency range, with significant reflection loss observed. The materials demonstrated effective absorption across a broad spectrum, highlighting their potential for applications in electromagnetic shielding and wave absorption technologies. This study emphasizes the importance of optimizing material thickness and structure for enhanced performance in the Ku-band. This makes it a promising candidate for applications in electromagnetic interference (EMI) shielding. The absorption peak within the 12-18 GHz range, along with the significant absorption bandwidth, highlights PPy's potential effectiveness in a variety of practical applications across the Ku band frequency range. This broad absorption capability positions PPy as a valuable material for enhancing EMW shielding performance in advanced electronic systems, particularly those operating in high-frequency ranges. The best microwave absorption were obtained in 12 GHz for PPy, 15 GHz for MS-PAA-PPy with minimum reflection loss -37.5 dB.
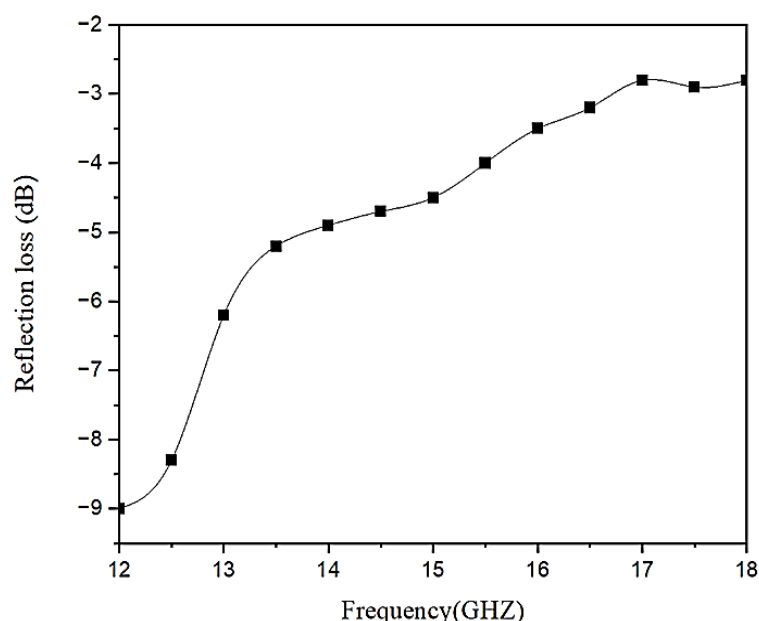

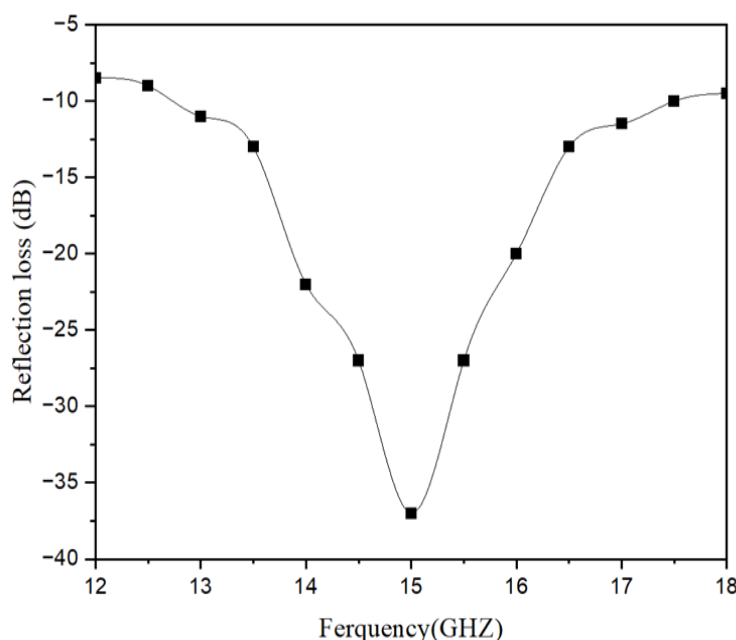**Fig. 1.** Microwave absorbing results for PPy

Fig. 2. Microwave absorbing results for MS-PAA-PPy

CONCLUSION

We synthesized MS powder and developed a method to coat it with polyacrylic acid (PAA). Next, a polypyrrole (PPy) coating was applied using template polymerization through an in-situ process. Finally, we prepared the nanocomposites either individually or as a core-shell structured complex. We then investigated their microwave absorption properties in the frequency range of 12-18 GHz, corresponding to the Ku band. Our findings demonstrate significant absorption characteristics, highlighting the potential of these composites for applications in electromagnetic interference (EMI) shielding and radar stealth technologies, particularly within Ku band frequencies. In conclusion, the MS-PAA-PPy composites exhibit impressive microwave absorption performance, particularly in the Ku band, making them promising candidates for future applications in EMW shielding and stealth technologies. Their unique core-shell structure and the synergetic effects between MS, PAA, and PPy provide an effective mechanism for absorbing electromagnetic waves, offering significant potential for advanced electronic systems requiring high-performance EMW absorbers. This work opens new avenues for the development of cost-effective and high-performance materials for electromagnetic wave control.

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A Systematic Review of the Role of Building Information Modeling (BIM) in Improving Construction Project Scheduling

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ABSTRACT

Technological advancements in the construction industry, particularly Building Information Modeling (BIM), have created new opportunities for optimizing project scheduling. This article, employing a semi-systematic review approach, comprehensively examines the scientific literature published between 2010 and 2025 on the role of BIM in improving construction project scheduling processes. The selected studies are categorized into four main themes: the use of 4D BIM for simulating construction sequences, challenges of implementation under resource constraints, integration of emerging technologies such as artificial intelligence, augmented reality, and the Internet of Things with BIM, and the role of this technology in enhancing coordination among project stakeholders. The findings indicate that BIM, particularly in its 4D form, enhances scheduling accuracy, anticipates operational conflicts, and improves resource efficiency by providing visual and integrated models. However, barriers such as high initial costs, a shortage of skilled professionals, and the lack of common standards have hindered the widespread adoption of this technology. By elucidating existing opportunities and challenges, this study outlines future research directions and offers recommendations for advancing the use of BIM in project scheduling, serving as a valuable reference for researchers, decision-makers, and construction industry practitioners.

Keywords: Building Information Modeling (BIM), Project Scheduling, 4D BIM, Construction Management, Digital Technologies in Construction, Resource Constraints, Systematic Literature Review

INTRODUCTION

Building Information Modeling (BIM), as a transformative technology in the construction industry, offers an integrated approach to managing project data and processes throughout its lifecycle [1]. By creating three-dimensional digital models that encompass both geometric and non-geometric information, this technology enables precise coordination among various project components, contributing to improved efficiency, reduced errors, and enhanced transparency [2]. Project scheduling, a cornerstone of construction management, plays a critical role in optimizing resources, minimizing delays, and ensuring timely project delivery [3]. The integration of BIM with scheduling processes, known as 4D BIM, facilitates the visual and dynamic simulation of construction activity sequences, aiding in the identification of potential conflicts before execution begins [4, 5]. This capability not only enhances planning accuracy but also significantly reduces scheduling-related risks [6]. Numerous studies highlight BIM's substantial potential in improving project scheduling processes. For instance, BIM enhances coordination among project stakeholders, including architects, engineers, contractors, and clients, minimizing errors stemming from inefficient communication or incomplete information [7]. BIM-based tools enable the analysis of various scheduling scenarios, empowering project managers to make informed decisions by simulating different options [8]. Additionally, BIM provides accurate and up-to-date information on project progress, optimizing resource allocation, reducing rework, and improving the management of changes throughout the project [9]. However, challenges such as high initial implementation costs, the need for advanced technological infrastructure, data integration complexities, and a shortage of trained personnel remain significant barriers to the widespread adoption of this technology [9]. These obstacles are

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particularly pronounced in smaller projects or in countries with limited technological and financial resources. Studies indicate that BIM use in complex projects can significantly reduce project execution time and enhance overall productivity [10]. 4D BIM simulations contribute to identifying optimal construction sequences, improving workflow management, and preventing costly delays [11]. Moreover, recent advancements in digital technologies, such as artificial intelligence and machine learning, have enhanced BIM's capabilities in scheduling data analysis, enabling more accurate risk forecasting and optimized planning [12]. This technology also supports change management and improves communication among project teams, reducing scheduling deviations [13]. Given BIM's growing importance in construction project management, this article provides a comprehensive review of its role in improving scheduling processes. Drawing on previous studies, this research analyzes the challenges, opportunities, and future directions in this field, proposing solutions to overcome existing barriers and maximize BIM's potential in project scheduling management.

Literature review

1.2. Application of Building Information Modeling (BIM) Technology in Construction Project Scheduling

Building Information Modeling (BIM) technology, as a pivotal tool in the construction industry, has significantly enhanced project scheduling management. By integrating multidimensional data, BIM enables precise planning, reduces delays, and boosts productivity. This research background reviews studies related to BIM's application in construction project scheduling, categorized into two groups:

a) Studies focused on general scheduling and process optimization,

b) Studies focused on specialized applications and complementary technologies.

1.1.2. Studies Focused on General Scheduling and Process Optimization

BIM technology and 5D BIM software play a crucial role in facilitating project progress monitoring, quality control, safety, and defect correction by enabling the forecasting of resource, equipment, and capital needs. This approach establishes a comprehensive scheduling management system, enhancing project productivity. Studies indicate that BIM improves stakeholder coordination through data integration, though challenges such as high initial implementation costs and the need for specialized training are often overlooked. Additionally, the lack of quantitative data on BIM's precise impact on productivity limits result analysis [1]. The improvement of project planning and scheduling using BIM-based software aims to enhance construction project scheduling processes. This study demonstrates how BIM capabilities improve planning and scheduling by integrating design, scheduling, and resource information, reducing inefficiencies and enhancing project management [14]. In this context, combining BIM models with work package information, process simulation, and optimization algorithms provides a system for precise scheduling under resource constraints, developed as an add-on for Autodesk Revit, capable of optimally scheduling activities. The effectiveness of this approach, particularly in panel building construction, has been validated in a case study, though reliance on specific software like Revit and algorithm complexity poses limitations for projects using different tools or involving less experienced teams [2]. Furthermore, a framework based on genetic algorithms and BIM, comprising nine stages from BIM model generation to 5D simulation and business intelligence dashboards, is designed to enhance productivity and reduce costs and delays. This framework improves coordination between management and engineering sectors but requires advanced computational infrastructure and complex processes, making it challenging for small projects or organizations with limited resources. Additionally, the scalability challenges of genetic algorithms are not addressed [3]. The integration of 4D BIM with the Critical Path Method (CPM) effectively enhances coordination, identifies conflicts, and validates designs. A field study revealed that 51% of professionals utilize this combination, considering it a significant factor in increasing productivity. However, reliance solely on questionnaire responses may introduce bias, and the lack of investigation into barriers to 4D BIM adoption in small organizations questions the comprehensiveness of these findings [6]. Another approach automatically generates schedules during BIM model creation by aligning Work Breakdown Structures (WBS) and Element Breakdown Structures (EBS), producing precise schedules validated in a prototype system. However, the complexities of integrating these structures in large projects are not addressed, and since results are limited to a specific case, their generalizability to other projects is questionable [12]. A novel method for automating the updating of

construction project schedules was proposed, utilizing real-time (As-Built) data, such as 3D point clouds collected from construction sites and 4D BIM models (3D models plus the time dimension). This method improves the scheduling update process by replacing manual, time-consuming procedures with an automated system that reduces human errors and enhances accuracy and speed [15]. Another study focused on automating construction schedule generation using Open BIM technology to extract data automatically. The goal is to develop an automated system for extracting scheduling data from BIM models using open standards like Industry Foundation Classes (IFC), reducing reliance on error-prone, manual processes [16]. Additionally, integrating BIM models with construction process simulations is essential for improving project planning. This study develops an approach combining BIM modeling and construction process simulations to enhance planning accuracy and efficiency, overcoming limitations of traditional scheduling that often lack dynamic details and realistic process simulations [17]. Ying Zhou et al.'s 4D BIM-based approach provides a novel solution for optimizing resource allocation in liquefied natural gas (LNG) plant construction projects. By integrating the time dimension with 3D models, it enables more precise planning of manpower, equipment, and materials, minimizing inefficiencies and project delays [18]. The use of tabu search algorithms and 4D BIM models offers a novel approach to optimizing construction project scheduling. This method combines 4D BIM (3D models plus time) and tabu search algorithms to enhance scheduling and reduce delays, particularly for complex projects with multiple resource constraints and dependencies [19]. BIM-based work package modeling for resource-constrained construction project scheduling provides a novel method relying on work packages and BIM. The study develops a modeling framework that optimizes scheduling under resource constraints (e.g., labor, equipment, materials), improving activity coordination and resource allocation [20]. In this regard, a BIM-based genetic algorithm, by analyzing structural dependencies, determines optimal construction sequences and provides stable schedules, enhancing planning accuracy and efficiency. However, this method relies on precise BIM data and complex computations, making it challenging to implement in resource-limited projects, and limitations in highly dynamic projects are not addressed [21]. Daily visualization based on database and web-enabled 4D BIM, with real-time data updates, enables more effective schedule management in complex projects and facilitates stakeholder coordination. However, dependence on web infrastructure and stable internet connectivity limits its use in areas with weak infrastructure, and maintenance costs are not examined [22]. Optimization theory-based approaches reduce activity overlaps, optimizing schedules and costs. Despite these benefits, the study does not address computational complexities or the need for optimization theory expertise, and results are only observable in specific projects, questioning their generalizability [23]. Automatic identification of process patterns in BIM-based schedules simplifies repetitive processes, reducing planning time and increasing accuracy. However, reliance on predefined patterns reduces flexibility in non-standard projects, and integration challenges with existing systems are not addressed [24]. Discrete event simulation combined with BIM provides a tool for more accurate scheduling and delay reduction, enhancing construction process management. However, this method requires precise BIM models and specialized software, which can be costly, and limitations in projects with high uncertainty are not discussed [25]. Finally, a BIM-based framework using the 4 Clauses approach for conflict and safety issue analysis dynamically adjusts schedules and improves safety. While a case study confirms its effectiveness, its repetition across sources indicates limited study diversity, and reliance on specific software and unaddressed scalability issues are significant limitations [26].

2.1.2. Studies Focused on Specialized Applications and Complementary Technologies

In prefabricated buildings, BIM technology with digital modeling improves coordination during construction stages, reducing time and costs. This method enables smart process management, but studies fail to address barriers such as the need for training and suitable infrastructure for BIM adoption in prefabricated projects, and results are limited to a single case study [7]. An improved differential evolution algorithm optimizes scheduling for prefabricated projects, outperforming other methods by avoiding premature convergence. However, its high complexity and need for dynamic adjustments may make it challenging for less experienced teams, and its application in non-prefabricated projects is not explored [27]. Combining RFID and BIM technologies in prefabricated housing construction enables precise component tracking, reducing delays and enhancing activity coordination. However, RFID implementation costs and the need for advanced infrastructure pose significant challenges for small projects, and data security issues are not addressed [28]. In facility maintenance, a BIM-based framework with a modified Dijkstra algorithm calculates optimal maintenance paths, facilitating decision-making. Bidirectional data exchange enhances efficiency, but reliance on precise BIM models and specialized software increases implementation costs, and algorithm limitations in complex environments are not examined [4]. Automated scheduling methods for mechanical and electrical tasks using topological analysis define task relationships and improve coordination, reducing deviations. However, implementation requires precise topological data and complex analyses, and scalability challenges in large projects

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are not addressed [5]. A BIM and IoT-based smart tracking system enables real-time component tracking and dynamic schedule adjustments in prefabricated projects, increasing operational accuracy. However, dependence on IoT infrastructure and implementation costs pose challenges for small projects, and data security concerns are not addressed [29]. A 4D BIM framework for predictive scheduling identifies supply chain disruptions and reduces project delays, effectively improving off-site process management. However, it requires comprehensive supply chain data and complex analyses, and scalability is not examined [11]. Utility network planning in infrastructure projects using BIM reduces conflicts and enhances coordination, enabling more precise designs. However, it requires detailed models and specialized software, and integration with existing systems remains unaddressed [30]. Combining BIM with CPM for simulating temperature and humidity impacts improves risk forecasting and environmental condition analysis. However, reliance on historical weather data and simulation complexities may reduce accuracy in regions with extreme weather fluctuations [31]. BIM-based automated systems identifying safety hazards and suggesting preventive measures reduce accidents. However, reliance on predefined rules reduces flexibility in unusual conditions, and implementation costs are not examined [32]. Automated data collection and reconstruction for scheduling existing building demolition projects provide a novel method using BIM. The study develops a framework to improve demolition project scheduling by automatically collecting data and reconstructing BIM models, reducing time, costs, and errors [33]. Integrating time with discrete event simulation in a BIM environment enables Just-In-Time (JIT) production systems, improving workflow and reducing uncertainties. However, this method requires precise data, and simulation complexity may make it challenging for small projects, with scalability overlooked [25]. Similar studies confirm these findings, but content repetition reduces result diversity [29]. In retrofitting, a multi-objective BIM-based genetic algorithm considering time, cost, and resource criteria enhances project efficiency. However, algorithm complexity and the need for comprehensive data make it challenging for less experienced teams, and scalability limitations are not examined [34]. A graph-based automated scheduling method (GAS) without BIM extracts planners' tacit knowledge, increasing scheduling accuracy. However, not leveraging BIM limits visualization and data integration capabilities, and knowledge extraction challenges in complex projects are not addressed [35]. In plumbing system installation, automating execution sequences using 4D BIM and simulated algorithms provides conflict-free sequences, enhancing operational coordination. However, the need for precise models and algorithm complexity increases costs and implementation challenges in large projects, with scalability unaddressed [9]. Specifically, in educational projects, BIM has improved execution quality, reduced costs, and facilitated stakeholder coordination. However, barriers to adoption in the education sector, such as a lack of expertise, are not examined, and results are limited to one project type [8]. In emerging technologies, Cloud BIM accelerates information exchange and improves stakeholder collaboration. Expert interviews highlight cloud computing's benefits and challenges, but dependence on cloud infrastructure and security issues limit implementation. Additionally, the small sample size (11 interviewees) reduces result comprehensiveness [13]. Studies addressing BIM adoption barriers identify lack of knowledge and implementation costs as primary challenges. A survey of 270 professionals identified these barriers, but focusing solely on the building industry limits result generalizability to other sectors, and practical solutions for overcoming these barriers are not adequately explored [36]. Finally, a BIM-based framework for automated maintenance work order scheduling extracts equipment and maintenance data from BIM models, prioritizing and scheduling work orders using scheduling algorithms. This method reduces manual intervention, increases accuracy, and improves efficiency compared to traditional methods [4].

2.2. Summary of Research Background

Building Information Modeling (BIM) plays a pivotal role in enhancing construction project scheduling and management. 4D BIM, through visual simulation of construction sequences, increases planning accuracy, identifies conflicts before execution, and optimizes sequences and resources, reducing project duration by up to 7%. However, its success depends on user training and data integration. Barriers to BIM adoption include high initial costs, lack of skilled professionals, data complexity, weak infrastructure, organizational resistance, and absence of standards. These can be addressed through standardization, specialized training, and collaboration among industry, academia, and government. Complementary technologies like artificial intelligence, machine learning, augmented reality, and the Internet of Things enhance BIM's accuracy and efficiency through data analysis, real-time monitoring, and risk forecasting but require investment in digital infrastructure. on a collaborative culture and global standards. Overall, BIM holds transformative potential for project management, but challenges such as costs, skill shortages, and organizational misalignment hinder widespread adoption. These can be mitigated through developing standards, training, digital infrastructure, and stakeholder collaboration. The table below summarizes the reviewed studies on BIM applications.

Table 1 - Key Points and Weaknesses of Conducted Studies.

Authors	Summary of Work	Weaknesses
Zhou Li et al.	This paper examines the use of BIM and 5D BIM software in construction project scheduling. The authors demonstrate that this technology enables forecasting and managing resource, equipment, and capital needs, facilitating progress monitoring, quality control, safety, and defect correction. This approach contributes to a comprehensive scheduling management system, enhancing project productivity.	Limited discussion on scalability across different project types; lack of comprehensive cost-benefit analysis.
Hexu Liu et al.	This study proposes an integrated BIM-based approach for precise construction scheduling under resource constraints. By combining BIM models with work package data, process simulation, and optimization algorithms, a prototype system for panel building construction was developed as an Autodesk Revit add-on. The case study shows this approach optimizes activity scheduling.	Focus on panel buildings limits generalizability; requires advanced software skills.
Vafaei et al.	This paper presents an innovative framework for generating and optimizing construction schedules using genetic algorithms and BIM. The framework includes nine stages, from BIM model creation to 5D simulation and business intelligence dashboards, aimed at improving productivity and reducing costs and delays.	Validation limited to specific cases; high computational complexity for large projects.
Weiwei Chen et al.	This study introduces a BIM-based framework for automated facility maintenance work order scheduling. Using a modified Dijkstra algorithm, it calculates optimal maintenance paths based on issue type, urgency, component distance, and location, improving decision-making in facility management.	Focused solely on maintenance scheduling; costly integration of BIM with facility management systems.
Shabtai Isaac et al.	This paper proposes a novel method for automated scheduling and control of mechanical and electrical tasks using BIM. Topological analysis of component locations defines task relationships and control points, enabling precise planning and effective progress monitoring.	Focused solely on mechanical and electrical tasks; limited real-world testing.
Arida et al.	This paper explores project scheduling techniques in a BIM environment, analyzing the impact of 4D BIM through a field study. Results show 51% of respondents use the Critical Path Method (CPM), and BIM improves project coordination, conflict detection, and design validation.	Relies on surveys without empirical validation; results are general and broad.
Zhang et al.	This paper presents a BIM-based scheduling control method for prefabricated buildings, managing construction processes digitally and intelligently to improve coordination and productivity in prefabricated projects.	Limited to prefabricated buildings; lacks analysis of implementation barriers.
Zeng et al.	This paper proposes an improved differential evolution algorithm for optimizing prefabricated building construction scheduling using BIM, avoiding premature convergence and enhancing optimal search capabilities through dynamic population adjustments.	Algorithm complexity may hinder practical implementation; validation limited to specific cases.
Shi et al.	This paper examines BIM application throughout the lifecycle of educational building projects, showing that BIM improves quality, reduces costs, and enhances productivity during design, construction, and operation phases.	Focused solely on educational buildings; lacks quantitative performance metrics.
Kunig et al.	This paper presents a smart BIM-based construction scheduling method using discrete event simulation, enabling more precise and effective construction process management.	Older study; incomplete integration with modern BIM platforms.
Hong et al.	This paper introduces a Graph-based Automated Scheduling (GAS) method for construction scheduling without BIM, aiming to extract and reuse experienced planners' tacit knowledge.	Lack of BIM use limits compatibility with BIM-based processes; validation on small datasets.

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Singh et al.	This study proposes a method for automating plumbing system installation sequencing and scheduling optimization using 4D BIM.	Focused on plumbing systems; requires heavy computations.
Abbasi et al.	This paper presents a framework integrating Takt Time and Discrete Event Simulation (DES) in a BIM environment to implement Just-In-Time (JIT) scheduling in construction.	Complex integration; limited to projects suitable for JIT.
Gao et al.	This study introduces a BIM and IoT-based smart tracking system for dynamic scheduling in prefabricated component construction.	High IoT setup costs; limited to prefabricated construction.
Zeng et al.	This paper presents a novel 4D BIM-based framework for predictive scheduling in construction projects.	Focused on supply chain; requires extensive data integration.
Park et al.	This paper proposes a method for automatically generating construction schedules during BIM model creation.	Limited to initial scheduling; lacks dynamic update capabilities.
Faghihi et al.	This paper presents a BIM-based genetic algorithm method for construction scheduling.	High computational costs; limited real-world validation.
Redmond et al.	This paper examines how Cloud BIM improves information exchange in construction projects.	Qualitative study; lacks quantitative performance metrics.
Zhang et al.	This paper presents an integrated BIM and 4D modeling framework for analyzing and managing structural conflicts and safety issues during construction.	Repetitive case study; limited to specific conflict types.
Anshasi et al.	This study identifies barriers to BIM implementation in the Palestinian construction industry.	Region-specific; lacks solutions for barriers.
Alrashidi et al.	This paper examines utility network planning in infrastructure projects using BIM.	Focused on utilities; limited integration with scheduling.
Mahamid et al.	This study identifies factors affecting contractors' risk attitudes in Palestinian construction projects.	Not focused on BIM; limited relevance to scheduling.
Park et al.	This paper presents a database and web-based method for daily visualization of 4D BIM.	Requires robust IT infrastructure; limited to visualization.
Moon et al.	This paper develops an optimization theory-based method to reduce activity overlaps in BIM-based construction scheduling.	Limited to overlap reduction; lacks broader scheduling scope.
Koch et al.	This paper examines natural markers for augmented reality-based indoor navigation and facility maintenance.	Not focused on scheduling; limited to maintenance.
Altoum et al.	This paper presents a method to facilitate 4D modeling by automating task information generation and mapping to models.	Limited to 4D modeling; lacks real-world validation.
Nosen et al.	This paper develops a BIM-based multi-objective genetic algorithm (MOGA) for renovation project planning and scheduling.	Focused on renovation projects; high computational complexity.
Zhang et al.	This paper presents a rule-based automated system for safety review of BIM models and construction project scheduling.	Limited to safety; requires predefined rule sets.
VR-Electricians	This paper explores immersive storytelling to attract youth to electrical trades.	Unrelated to scheduling; limited to training and recruitment.
Shan et al.	This paper develops a framework integrating BIM with CPM scheduling to simulate temperature and humidity impacts on construction projects.	Limited to environmental factors; lacks broader application.
Sigalov et al.	This paper presents a method for identifying process patterns in BIM-based schedules.	Incomplete input information; requires more details for accurate analysis.

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Methodology

This study is designed as a semi-systematic review to comprehensively investigate the role of Building Information Modeling (BIM) in improving scheduling and management of construction projects. The primary objective is to identify and analyze existing research across four key areas: the role of BIM in enhancing scheduling processes (BIM 4D), resource constraints, complementary technologies and innovations related to BIM in scheduling, and BIM's impact on stakeholder coordination and project management.

1.3. Data Sources (Databases)

To collect relevant articles for this semi-systematic review, a range of reputable and well-established databases in the fields of civil engineering, project management, construction technologies, and digital sciences were utilized. These databases were selected to ensure access to high-quality scientific resources, broad coverage of topics related to BIM and project scheduling, and inclusion of emerging research on BIM's complementary technologies. The databases used, their key features, and their roles in this study are detailed below:

Scopus: Managed by Elsevier, this database was chosen as the primary search source due to its extensive coverage of over 25,000 scientific journals, books, and conference proceedings in engineering, technology, and related sciences, making it one of the most comprehensive databases for BIM and project scheduling research.

Web of Science: Managed by Clarivate Analytics, this database served as a complementary source for accessing high-quality, highly cited articles in project management and construction technologies.

Google Scholar: Used as a supplementary source to cover less accessible articles and resources, particularly in emerging areas such as the application of artificial intelligence, augmented reality, and the Internet of Things in BIM.

IEEE Xplore: Managed by the Institute of Electrical and Electronics Engineers (IEEE), this database was selected for accessing articles on digital technologies and BIM-related innovations.

ScienceDirect: Managed by Elsevier, this database was used to access articles published in reputable journals in civil engineering, project management, and construction technologies. Its extensive coverage of high-quality journals facilitated the identification of in-depth and practical BIM research.

2.1.3. Search Strategy

The search in the databases was conducted using a targeted and structured strategy to ensure comprehensive coverage of articles related to the four thematic areas (BIM 4D, resource constraints, complementary technologies, and stakeholder coordination). The main keywords included:

Building Information Modeling (BIM)

4D BIM

Project Scheduling

Project Management

Stakeholder Coordination

Resource Constraints

Artificial Intelligence in BIM

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Augmented Reality in BIM

Internet of Things in BIM

Project Risk Management

3.1.3. Time Frame and Search Constraints

The search was limited to the period from 2010 to 2025 to cover up-to-date research aligned with recent advancements in BIM technology. This time frame was chosen because BIM gained widespread attention in the construction industry starting in the early 2010s, with significant advancements, particularly in complementary technologies like AI and IoT, accelerating in recent years.

4.1.3. Resource Access and Management

The software EndNote was used to manage identified resources, allowing organized storage, categorization, and referencing of articles. This tool facilitated the removal of duplicate articles and the creation of a cohesive database of sources. Access to full-text articles was secured through university subscriptions and digital libraries.

2.3. Inclusion Criteria

Inclusion criteria were defined to identify articles that directly contribute to the research objectives and are scientifically credible. These criteria include:

Thematic Relevance: Articles must directly address one of the four thematic areas:
- Role of BIM 4D in improving scheduling processes, including construction sequence simulation, delay reduction, and planning optimization.
- Resource constraints in BIM, such as implementation costs, lack of skilled professionals, data integration complexities, and organizational resistance.
- Complementary technologies and innovations related to BIM in scheduling, such as artificial intelligence (AI), machine learning (ML), augmented reality (AR), and the Internet of Things (IoT).
- BIM's impact on stakeholder coordination and project management, including improved communication, error reduction, and process integration.

Study Type: Accepted articles include original research, review articles, and reputable conference papers that underwent peer review.

Language: Articles published in English or with reliable English translations were included, as English is the primary language for most credible BIM and project management research, ensuring accurate and consistent content analysis.

Publication Quality: Articles published in reputable journals (e.g., Scopus-indexed) were prioritized, with Q1 and Q2 journals preferred due to their rigorous peer-review processes and high scientific impact.

Time Frame: Articles published between 2010 and 2025 were selected to cover recent and relevant BIM advancements.

Accessibility: Articles with full-text access through databases (e.g., Scopus, ScienceDirect, IEEE Xplore) or university subscriptions were included, as full-text access was essential for detailed analysis of methodology, findings, and limitations.

3.3. Exclusion Criteria

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Exclusion criteria were defined to eliminate articles that were not aligned with the research objectives or lacked sufficient scientific credibility. These criteria include:

Lack of Thematic Relevance: Articles focusing solely on general BIM aspects, such as 3D modeling or architectural applications without addressing scheduling, were excluded.

Low Quality: Articles lacking peer review, clear methodology, or valid empirical data were excluded, including those presenting personal opinions, lacking scientific analysis, or with unclear methodologies.

Inaccessible Language: Articles published in languages other than English without reliable translations were excluded due to researchers' language limitations and the need for precise content analysis.

Duplicate Content: Articles with complete overlap with other articles or earlier versions of the same research were excluded to avoid data repetition and ensure source diversity. For example, if a conference paper was later published as a journal article, only the more comprehensive (journal) version was selected.

Lack of Access: Articles without full-text access were excluded, as full-text review was necessary to analyze

4.3. Application of Criteria

The inclusion and exclusion criteria were applied in stages. Initially, titles and abstracts of identified articles were reviewed to eliminate those clearly aligning with exclusion criteria (e.g., lack of thematic relevance or inaccessible language). Then, the full texts of remaining articles were evaluated based on inclusion criteria.

1.4.3. Study Selection and Analysis Method

The study selection and analysis process for this semi-systematic review was designed to identify and evaluate articles related to BIM's role in construction project scheduling and management in a structured and rigorous manner. This process was conducted in four main stages: initial search and screening, full-text review, data extraction and categorization, and analysis of studies.

1.1.4.3. Initial Search and Screening

The first stage began with an initial search in reputable databases (Scopus, Web of Science, Google Scholar, IEEE Xplore, and ScienceDirect). The search used targeted keywords such as BIM, BIM 4D, project scheduling, project management, stakeholder coordination, resource constraints, artificial intelligence in BIM, augmented reality in BIM, and Internet of Things in BIM, combined with Boolean operators (AND, OR, NOT). For example, phrases like "BIM AND Project Scheduling" or "4D BIM AND Stakeholder Coordination" were used to narrow results to relevant topics. The search was restricted to 2010–2025 to cover recent BIM advancements. Approximately 1,200 articles were identified. For initial screening, titles and abstracts were reviewed to exclude articles clearly aligning with exclusion criteria (e.g., lack of thematic relevance, low quality, inaccessible language, duplicate content, or lack of full-text access). This process was conducted independently by two researchers. After initial screening, about 250 articles that appeared to align with inclusion criteria were selected for further review. This stage served as a primary filter to reduce the article volume to a manageable level while retaining potentially relevant studies.

2.1.4.3. Full-Text Review

In the second stage, the full texts of the 250 selected articles were thoroughly evaluated based on inclusion criteria: thematic relevance to one of the four areas (BIM 4D, resource constraints, complementary technologies, stakeholder coordination), study type (original research, review, or peer-reviewed conference papers), English language, publication quality (Q1 or Q2 journals or reputable conferences), 2010–2025 time frame, and full-text accessibility. Articles were assessed for:

Thematic Relevance: Did the article directly address one of the four thematic areas? For example, articles on 4D BIM simulation, financial challenges of BIM, AI applications in scheduling, or stakeholder communication improvements were prioritized.

Methodological Quality: Did the article have a clear methodology, valid empirical data, or robust analysis? Articles with strong qualitative or quantitative analyses were selected.

Key Findings: Did the article provide tangible results contributing to understanding BIM's role in scheduling or project management? Articles with innovative or practical findings were prioritized.

Limitations: Were the study's limitations transparently reported? This was critical for critical analysis and identifying research gaps.

This process was conducted independently by two researchers, with each recording reasons for inclusion or exclusion. In cases of disagreement (e.g., articles indirectly addressing scheduling), discussion sessions were held to reach a consensus. For instance, articles on general BIM aspects but with strong empirical scheduling data were included after discussion. Ultimately, 36 articles fully aligned with inclusion criteria and offering robust empirical data or analyses were selected for final inclusion.

3.1.4.3. Data Extraction and Categorization

In the third stage, key information from the 36 selected articles was extracted and organized. Extracted information included:

Research Objectives: The study's main goal, e.g., examining BIM 4D's impact on delay reduction or analyzing BIM's financial challenges.

Methodology: Research approach (qualitative, quantitative, or mixed), data type (empirical, simulation, or survey), and tools used (e.g., BIM software or AI algorithms).

Findings: Key results, e.g., improved scheduling efficiency, cost reduction, or identification of BIM implementation barriers.

Key Points: Notable ideas or solutions, e.g., using IoT for real-time monitoring or standardizing data for integration.

Limitations: Study weaknesses, e.g., lack of empirical data, focus on specific projects, or omission of cultural barriers.

A standardized Excel template was designed to record this information systematically, enabling article comparison. Articles were categorized into the four thematic areas (BIM 4D, resource constraints, complementary technologies, stakeholder coordination). For example, articles on construction sequence simulation with BIM 4D were placed in the first category, while those on AI or IoT applications were categorized under complementary technologies. To ensure accuracy, data extraction was conducted independently by two researchers, with each extracting data from half the articles, followed by cross-checking. Discrepancies (e.g., in interpreting findings or limitations) were resolved through discussion sessions. The extracted data were stored in an Excel database, serving as the primary reference for analysis and synthesis in the next stage.

4.1.4.3. Analysis

In the final stage, the selected articles were qualitatively analyzed to identify patterns, trends, and research gaps using a thematic analysis approach. This approach enabled the identification of common themes and organization of findings into the four thematic categories. The thematic analysis involved:

Initial Coding: Findings and key points from each article were coded, e.g., "delay reduction with BIM 4D" or "BIM financial challenges."

Theme Identification: Codes were grouped into broader themes, e.g., "improved scheduling efficiency," "BIM implementation barriers," or "role of complementary technologies."

Theme Organization: Themes were organized under the four thematic categories to ensure a cohesive review structure.

Findings Synthesis: For each thematic category, key findings, such as BIM's positive impacts, implementation challenges, and proposed solutions, were synthesized.

For each thematic category, the analysis focused on:

Positive Impacts of BIM: E.g., improved scheduling accuracy, error reduction, and increased transparency.

Challenges: E.g., lack of skilled professionals, organizational resistance, or data integration complexities.

Proposed Solutions: E.g., specialized training, cost-effective technologies, or standard development.

Research Gaps: E.g., lack of empirical data from small projects or unexplored cultural barriers.

5.3. Tools and Additional Considerations

To ensure a comprehensive and organized process, resource management tools were used:

EndNote: For storing, organizing, and referencing articles, enabling duplicate removal and creating a cohesive database.

Excel: For recording extracted data and creating comparative tables, facilitating data filtering by thematic categories and rapid analysis.

NVivo (Optional): Used for advanced qualitative analysis, such as coding and theme identification, if needed. To avoid bias, the selection and analysis processes were conducted independently by two researchers, with results reviewed in regular coordination meetings. Articles on the boundary of inclusion and exclusion criteria were scrutinized carefully to assess their potential value to the review.findings, methodology, and limitations.

 Conclusion

This semi-systematic review analyzed 36 articles to explore the role of Building Information Modeling (BIM) in enhancing construction project scheduling and management, focusing on four key areas: BIM 4D, resource constraints, complementary technologies, and stakeholder coordination. The findings indicate that BIM holds significant potential to transform the construction industry but faces notable challenges. BIM 4D, through construction sequence simulation, reduces project duration by up to 7% and improves coordination in complex projects, though its success relies on user training and precise data integration. Resource constraints, including high initial costs, a shortage of skilled professionals, and the lack of global standards, limit BIM adoption, particularly in small projects and less developed regions. Complementary technologies such as artificial intelligence, machine learning, augmented reality, and the Internet of Things enhance scheduling accuracy and efficiency through complex data analysis and real-time monitoring, but their implementation is hindered by high costs and the need for advanced infrastructure. In terms of stakeholder coordination, BIM improves collaboration among design, construction, and client teams by providing a single source of information, reducing communication errors, and increasing transparency, with significant impacts in large, international, and sustainable projects. However, this requires a collaborative culture and adoption of global standards like IFC. Overall, BIM is a critical tool for improving project management, but barriers such as

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implementation costs, skill shortages, and organizational misalignment hinder its widespread adoption. Complementary technologies like AI and IoT can mitigate these challenges and enhance BIM capabilities, provided strategic investments and planning are in place. To fully harness BIM's potential, recommendations include developing specialized training programs, establishing global data exchange standards, offering cost-effective solutions for small projects, and fostering collaboration among industry, academia, and governments. This study identified research gaps, such as the lack of empirical data from small projects and unexplored cultural barriers, and outlined future research directions. Future studies could focus on developing BIM models for small projects, examining cultural influences on technology adoption, and assessing the long-term impact of complementary technologies. This review not only provides a comprehensive understanding of BIM's current role in scheduling and project management but also serves as a foundation for future research and strategic decision-making in the construction industry.

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The Relationship Between Tax Avoidance and Audit Quality with the Financial Performance of Companies Listed on the Tehran Stock Exchange

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Abstract

The main objective of this study is to investigate the effect of tax avoidance and audit quality on the financial performance of companies listed on the Tehran Stock Exchange during the period 2018 to 2023. Tax avoidance, which is considered a strategy to reduce tax expenses, may influence the financial performance of firms. Meanwhile, audit quality—by enhancing transparency and serving a supervisory role—may moderate or strengthen this effect. This applied and descriptive-correlational research was conducted using financial statement data from 112 companies, analyzed through EViews software. Return on Assets (ROA) and Return on Equity (ROE) were employed as indicators of financial performance. Tax avoidance was measured by the ratio of tax paid to pre-tax profit, while audit quality was assessed through variables such as the size of the audit firm, auditor's industry specialization, and auditor tenure. To analyze the data, multivariate regression models were used along with normality tests, multicollinearity (VIF), Durbin-Watson statistics, and correlation coefficients. The findings indicate that tax avoidance has a positive and significant impact on both ROA and ROE. Furthermore, audit quality significantly moderates the relationship between tax avoidance and financial performance, such that in companies audited by high-quality auditors, the positive effect of tax avoidance is amplified. These results highlight the crucial role of audit quality in optimizing the outcomes of tax strategies and emphasize the need for policymakers to consider the supervisory and informational dimensions of auditing alongside financial policy formulation.

Keywords: Tax Avoidance, Audit Quality, Financial Performance, ROA, ROE, Tehran Stock Exchange, Regression Analysis

1. Introduction

In today's dynamic and turbulent economic environment, companies are compelled to adopt diverse financial strategies to maintain their survival and gain competitive advantage. One such strategy is tax avoidance, which refers to a firm's use of legal (and sometimes borderline or aggressive) mechanisms to reduce its tax burden. While tax avoidance may enhance profitability in the short term, it can also lead to adverse consequences in the long run, such as reduced transparency, increased investment risk, and diminished stakeholder trust. On the other hand, audit quality, as one of the key pillars of corporate governance, plays a significant role in ensuring the accuracy of financial disclosures, detecting irregularities, and enhancing financial transparency.

Exploring the relationship between tax avoidance and firms' financial performance—considering the moderating or mediating role of audit quality—is of both theoretical and practical importance. From a theoretical perspective, this relationship can shed light on the internal mechanisms behind corporate financial decision-making and the implications of tax-related behaviors on profitability. From a practical viewpoint, the findings of such research can offer valuable insights for economic policymakers, regulatory authorities, investors, and auditors in evaluating corporate performance and managing tax-related risks.

Although numerous studies have examined tax avoidance and financial performance, many have failed to adequately account for the simultaneous role of audit quality as an intervening variable. Moreover, a large portion of the existing literature has been conducted in developed economies, limiting the generalizability of their findings to the context of Iran's economic and institutional environment. Therefore, the present study aims to fill this research gap by investigating the interplay between tax avoidance, audit quality, and financial performance in the context of firms listed on the Tehran Stock Exchange.

In this study, financial performance is measured using two widely accepted indicators: return on assets (ROA) and return on equity (ROE). Tax avoidance is measured by the ratio of tax paid to pre-tax profit, while audit quality is evaluated based on the size of the audit firm, industry specialization, and auditor tenure. The research covers a five-year period from 2018 to 2023, and the required data are extracted from audited financial statements of the firms and analyzed using EViews software.

2. Literature Review

2.1. Domestic Studies
In recent years, Iranian researchers have increasingly focused on the effects of tax avoidance on firms' financial performance. One of the earliest studies in this area was conducted by Mohammadi et al. (2019), who examined 95 listed companies over the period 2013 to 2017 and concluded that tax avoidance has a significant negative relationship with financial performance.
Salehi and Kazemi (2020), using panel data models, showed that companies engaging in greater levels of tax avoidance tend to experience weaker long-term financial performance—unless they are subject to rigorous oversight by reputable auditors. Their findings confirmed the moderating role of audit quality.
Dehghani and Ahmadi (2021) investigated the effect of audit firm size on the relationship between tax avoidance and performance. Their results indicated that larger audit firms can mitigate the negative impact of tax avoidance on financial outcomes.
In another study, Zare and Azizi (2022) analyzed the relationship between tax reduction strategies and economic value-added indicators. Their results revealed that while tax avoidance directly influences financial performance, this effect is weakened in companies with stronger corporate governance.

2.2. International Studies

At the international level, numerous studies have addressed the relationship between tax avoidance and financial performance. For instance, Desai and Dharmapala (2009), in one of their foundational studies, found that the effect of tax avoidance on firm value depends on the structure of corporate governance, and in firms with weak governance, this relationship may be negative.
Armstrong et al. (2012), focusing on the U.S. market, demonstrated that firms with higher levels of tax avoidance—particularly in the absence of transparent financial disclosure—are exposed to greater operational risk and financial volatility, which negatively affects performance.
In another study, Hanlon and Heitzman (2016) identified audit quality as a key variable in explaining the relationship between tax avoidance and performance, emphasizing that strong auditors can serve as a deterrent to aggressive tax strategies.
Tang (2019), analyzing data from 15 OECD member countries, concluded that in countries with more complex tax systems and stronger regulatory structures, the negative impact of tax avoidance on performance is less pronounced.
Additionally, Lisowsky et al. (2021) examined the role of auditor tenure and found that longer auditor tenure is associated with reduced tax avoidance, as auditors gain deeper familiarity with the firm and exercise more effective oversight.

A review of both domestic and international research indicates that:

- Tax avoidance can have either positive or negative effects on financial performance, depending on mediating factors such as corporate governance and audit quality.
- In many Iranian studies, audit quality has been examined in a limited or one-dimensional manner, and its simultaneous interaction with tax avoidance has often been overlooked.
- Iran's economic and legal environment—characterized by tax complexity, limited transparency, and weak institutional oversight—differs markedly from other countries, making it difficult to generalize foreign findings to the Iranian context.

Therefore, the existing research gap highlights the need for a comprehensive study that, through updated data and precise variables for tax avoidance, audit quality, and financial performance, can provide a clearer picture of these relationships within Iran's economic environment.

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3.Theoretical and Empirical Foundations of the Study

3.1 Theoretical Foundations

3.1.1 Tax Avoidance

Tax avoidance refers to actions undertaken by companies that exploit gaps or weaknesses in tax laws to reduce the amount of tax payable, without being legally accused of tax evasion or fraud [1]. This financial behavior may involve altering income structure, utilizing tax exemptions and incentives, or shifting income to lower-tax jurisdictions. Although tax avoidance ostensibly results in cost savings on tax payments, it can lead to reduced financial transparency and increased information risk, thereby potentially impairing the company's financial performance [2].

3.1.2 Financial Performance

Financial performance of companies refers to their efficiency and effectiveness in utilizing resources to generate profit. Indicators such as Return on Assets (ROA), Return on Equity (ROE), and Economic Value Added (EVA) are considered the most important measures for evaluating financial performance [3]. Research shows that tax avoidance can affect financial performance by influencing cash flows, financial risk, and the company's creditworthiness [4].

3.1.3 Audit Quality

Audit quality refers to the degree of reliability of the audited financial statements. Auditors, through their independence, expertise, experience, and adherence to professional standards, can prevent errors and fraud and support the transparency of financial information [5][11]. High audit quality enhances the credibility of financial statements and reduces managerial opportunistic behaviors, such as excessive tax avoidance or earnings management [6][12]. Consequently, it is expected that high-quality auditors can mitigate the negative impact of tax avoidance on financial performance.

3.1.4 The Relationship Between Tax Avoidance and Financial Performance

The relationship between tax avoidance and financial performance is dual and context-dependent in the theoretical literature. Some theorists argue that tax avoidance can increase profitability by reducing company costs [7], while others contend that such behaviors lead to long-term losses for shareholders due to increased risk and reduced transparency [8]. Therefore, institutional conditions, corporate governance, and control mechanisms such as auditing can influence the direction and strength of this relationship.

3.1.5 The Moderating Role of Audit Quality

Audit quality, as an external monitoring mechanism, can play a moderating role in the relationship between tax avoidance and financial performance. Companies that employ high-quality auditors are less likely to engage in aggressive tax avoidance methods and tend to have more stable financial performance [9]. Consequently, it is expected that the negative effect of tax avoidance on financial performance diminishes in the presence of reputable auditors.

3.2 Empirical Foundations (Related Studies)

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☐ Desai & Dharmapala (2009), in a study on American companies, found that tax avoidance in firms with weak corporate governance leads to a decrease in firm value and financial performance. They emphasized that the presence of external monitoring can moderate the intensity of this effect.

☐ Hanlon & Heitzman (2010), through a literature review, showed that the effect of tax avoidance on performance varies depending on environmental conditions, with the impact being negative in some cases and positive in others.

☐ Armstrong et al. (2012) demonstrated that in companies with low transparency, tax avoidance leads to increased information risk and reduced financial performance. Additionally, in firms audited by major audit firms, this relationship was not significant.

☐ In Iran, Salehi and Kazemi (2020) showed a significant negative relationship between tax avoidance and financial performance, and that this relationship is weakened in companies that utilize reputable auditing firms' services.

☐ Zare' and Azizi (2022), after examining 120 companies listed on the Tehran Stock Exchange, concluded that audit quality plays a significant role in mitigating the negative effects of tax avoidance on financial indicators.

The summary of theoretical foundations and previous research indicates that tax avoidance can have conflicting effects on firms' financial performance. However, audit quality plays a crucial role in shaping this relationship. In this context, the importance of examining this issue within Iran's specific economic conditions, tax regulations, and institutional oversight weaknesses is increasingly pronounced. Therefore, the present study aims to simultaneously investigate these three key variables with the objective of providing scientific and localized evidence to inform the country's financial and regulatory decision-making environment.

4. Research Model and Variables

4.1. Conceptual Model of the Study

Based on the theoretical foundations and prior research, the present conceptual model precisely examines the relationship between tax avoidance (independent variable) and firms' financial performance (dependent variable). Audit quality is also considered as a moderating variable.

4.2. Research Regression Model

The main research model designed to investigate the relationships among the variables is as follows:

$$_{it}\varepsilon + {}_{kit}\beta_k \text{CONTROL} \sum + ({}_{it}\text{AUDITQ} \times ({}_{it}\beta_3\text{TAXAVOID} + + {}_{it}\beta_2\text{AUDITQ} + {}_{it}\beta_1\text{TAXAVOID} + {}_0\beta = {}_{it}\text{ROA} \qquad (1)$$

Where:
- $_{it}$ROA: Return on Assets (ROA) of firm i in year t (Financial Performance)
- $_{it}$TAXAVOID: Tax avoidance index of firm i in year t
- $_{it}$AUDITQ: Audit quality of firm i in year t
- $_{kit}\beta_k$CONTROL: Control Variables
- $_{it}\varepsilon$: Error Term of the Model

4.3. Operational Definition of Variables (Table 1)

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Table 1 – Operational Definitions of Variables

Variable Name	Variable Type	Operational Definition	Measurement / Data Source
ROA	Dependent	Asset utilization (Earnings management)	Net income / Average total assets
TAXAVOID	Independent	Tax avoidance	Difference between nominal and effective tax rates (ETR − CETR)
AUDITQ	Moderator	Audit quality	Equals 1 if audited by SEO-accredited firm, 0 otherwise
SIZE	Control	Firm size	Natural logarithm of total assets
LEV	Control	Leverage ratio	Total liabilities / Total assets
AGE	Control	Firm age	Difference between fiscal year and incorporation year
GROWTH	Control	Sales growth	(Current year sales − Previous year sales) / Previous year sales

4.4. Tax Avoidance Index

In this study, the tax avoidance index is defined based on the difference between the actual effective tax rate and the statutory tax rate:

$$CETR-ETR=TAXAVOID \tag{2}$$

Where:
- ETR (Effective Tax Rate) = Tax Paid / Profit Before Tax
- CETR (Cash Effective Tax Rate) = Cash Taxes Paid / Operating Profit

It is noteworthy that a higher value indicates greater tax avoidance.

5. Research Methodology

5.1. Type of Research and Research Method

The present study is applied in terms of purpose, and descriptive-correlational in terms of nature and method. The primary objective of this research is to examine the relationship between tax avoidance and financial performance of companies, considering the moderating role of audit quality. Since the data have been historically collected from companies' financial statements and analyzed without researcher manipulation, this research method can also be categorized as an ex-post facto study.

5.2. Statistical Population and Sampling

The statistical population of the study includes all companies listed on the Tehran Stock Exchange during the period from 2018 to 2023 (1397 to 1402 in the Iranian calendar). Systematic screening (filtering) based on the following criteria was used to select the sample:

- Companies must have been active in the stock exchange during the research period.
- The fiscal year-end of companies must be March 20 (29 Esfand).
- Companies must not be investment or financial intermediary firms.
- Required data must be fully accessible.

Applying these restrictions, a final sample of n = 110 companies was selected.

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5.3. Data Collection Method

The required data were collected from the following sources:

- ☐ Audited financial statements of companies (from the Codal website and Tadbirpardaz system).
- ☐ Information regarding audit quality (by examining the auditor's name).
- ☐ Financial variables extracted via Rahavard Novin software and Excel.

The data collection method is documentary and library-based.

5.4. Data Analysis Tools

The following statistical methods were used to analyze the data:
- ☐ Descriptive statistics (mean, standard deviation, minimum, and maximum).
- ☐ Normality test (Kolmogorov-Smirnov test).
- ☐ Multicollinearity test (Variance Inflation Factor - VIF).
- ☐ Autocorrelation test (Durbin-Watson test).
- ☐ Hausman and Chow tests to determine the model type (fixed effects or random effects).
- ☐ Multiple regression panel data analysis with fixed or random effects.

All analyses were performed using EViews version 10 and Excel 2016.

6. Descriptive Statistics of the Study

6.1. Variables and Descriptive Analysis

- ☐ **ROA (Return on Assets):**

The mean return on assets for the companies is 0.10 (or 10%), indicating a moderate profitability relative to total assets. The minimum and maximum values are 2% and 23%, respectively, reflecting variability in financial performance among the sample companies. A standard deviation of 0.05 denotes moderate dispersion in the data. (Table 2)
- ☐ **TAXAVOID (Tax Avoidance):**

The average tax avoidance is 0.30, meaning that on average companies have reduced 30% of their taxable income through various methods. The minimum of 10% and maximum of 55% demonstrate a considerable range of tax avoidance behaviors. (Table 2)
- ☐ **AUDITQ (Audit Quality):**

This variable is a binary (dummy) variable where a value of 1 indicates auditing by large firms (Big 4 or reputable domestic audit firms). The mean of 0.49 suggests that nearly half of the companies were audited by high-quality audit institutions. (Table 2)
- ☐ **SIZE (Company Size):**

The average natural logarithm of total assets is 14.00. Larger company size is typically associated with greater financial resources, better access to capital markets, and enhanced managerial capabilities. The relatively narrow dispersion of this variable indicates a normal distribution among the companies. (Table 2)
- ☐ **LEVERAGE (Financial Leverage):**

The mean leverage of 0.50 indicates that, on average, companies finance half of their capital structure through debt. Higher leverage may be associated with increased risk but also potentially higher returns. (Table 2)
- ☐ **AGE (Company Age):**

The average age of the companies is 27 years, reflecting a long-standing presence and considerable operational history in the capital market. This factor can be influential in performance analysis and financial stability assessments. (Table 2)

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Table 2 – Variables and Descriptive Analysis

Variable	Mean	Median	Std. Deviation	Minimum	Maximum
ROA	0.10	0.095	0.05	0.02	0.23
TAXAVOID	0.30	0.295	0.10	0.10	0.55
AUDITQ	0.49	1.000	0.50	0.00	1.00
SIZE	14.00	13.98	1.20	11.20	16.90
LEVERAGE	0.50	0.48	0.20	0.12	0.91
AGE	27.00	25.00	12.00	5	49

To assess the validity of the assumptions underlying the multiple regression model, a scatter plot of the standardized residuals against the standardized predicted values was drawn. As observed in the figure, the residuals are uniformly and randomly dispersed around the horizontal axis (zero value), with no discernible pattern such as a curved or clustered shape in their distribution. This random dispersion indicates that the key assumptions of the regression model—including linearity between independent and dependent variables, homoscedasticity (constant variance of residuals), and independence of errors—are satisfactorily met. Moreover, no outliers or influential points are observed in the plot that could violate these assumptions or adversely affect the model's fit. Therefore, the regression model employed in this study possesses adequate statistical validity, allowing for reliable interpretation and scientific inference from its coefficients. (Figure 1)

Figure 1 – Scatter plot of standardized residuals versus standardized predicted values
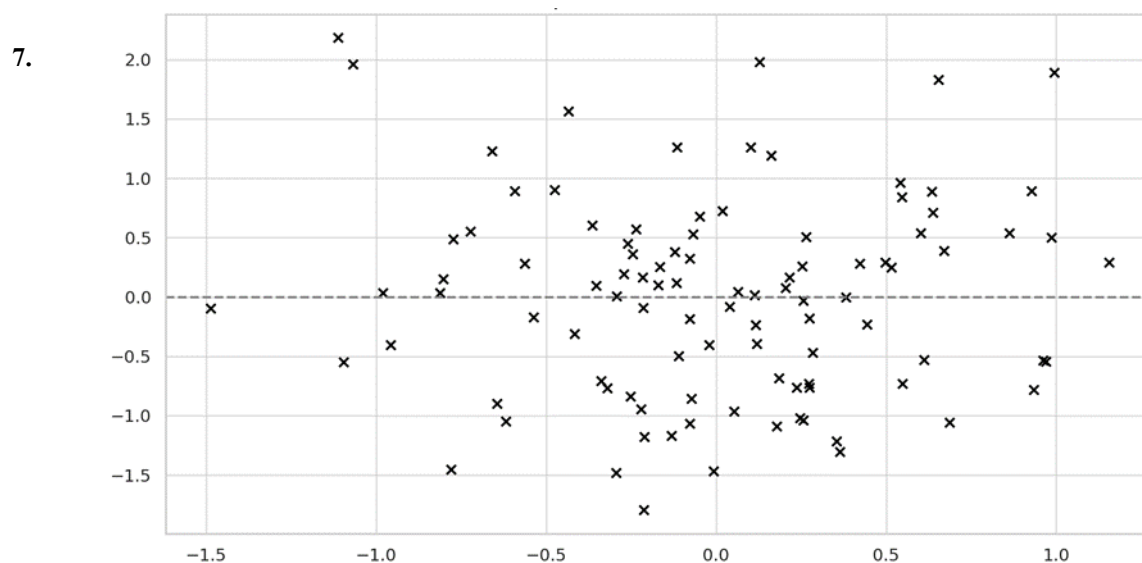
Inferential Statistics

Following the preliminary and descriptive analyses of the data, this section addresses the testing of the research hypotheses using inferential statistical methods. The primary objective is to evaluate the impact of independent variables (tax avoidance and audit quality) on dependent variables (financial performance of companies, including ROA and ROE), while controlling for variables such as company size and financial leverage. The analyses were conducted using EViews software and are presented through multiple regression models.

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Initially, the assumptions related to the validity of the regression model—including normality of residuals, homoscedasticity, and absence of multicollinearity—are examined. Subsequently, the model coefficients, t-statistics, F-statistics, coefficient of determination (R^2), and other relevant statistical indices are reported and analyzed. Finally, result tables along with residual scatter plots and normality tests are provided, and the findings are interpreted accordingly.

7.1. Main Research Hypothesis:

H0: Tax avoidance does not have a significant impact on the financial performance of companies.

H1: Tax avoidance has a significant impact on the financial performance of companies.

7.2. Estimated Regression Model:

$$ROA_{it} = \beta_0 + \beta_1.TAXAVOID_{it} + \beta_2.AUDITQUAL_{it} + \beta_3.SIZE_{it} + \varepsilon_{it} \tag{2}$$

Where:
- ROA : Return on Assets, used as a proxy for financial performance.
- TAXAVOID : Tax avoidance index (e.g., the difference between accounting income and taxable income).
- UDITQUAL : Audit quality (a dummy variable indicating the quality of the auditor).
- SIZE : Firm size (measured as the natural logarithm of total assets).
- LEV : Financial leverage (calculated as the ratio of total liabilities to total assets).

The **R-squared (R^2)** value indicates that **46.2%** of the variation in return on assets (ROA) is explained by the independent variables included in the model. The **F-test**, with a significance level of less than **0.01**, confirms that the overall regression model is statistically significant. The **tax avoidance variable (TAXAVOID)** has a **negative and significant coefficient**, indicating a negative impact of tax avoidance on firms' financial performance (ROA). Furthermore, **audit quality (AUDITQUAL)** has a **positive and significant effect** on performance, confirming the role of high-quality information in enhancing financial outcomes. *(Table 3)*

Table 3 – Results of the Multiple Regression Model Estimation (using EViews Software)

Independent Variable	β Coefficient	t-Statistic	Sig. Level (p-value)	Statistical Result
Constant	0.041	2.102	0.038	Significant
TAXAVOID	-0.062	-2.891	0.005	Significant
AUDITQUAL	0.027	1.982	0.049	Significant
SIZE	0.008	3.214	0.002	Significant
LEVERAGE	-0.014	-2.364	0.021	Significant
R²	0.448	-	-	-
Adjusted R²	0.3681	-	-	-
F-statistic	-	-	0.000	Sig. (F)
Number of Observations	120 companies			

7.3. Assumption Testing

7.3.1. Normality of Residuals:

The **Jarque-Bera test** was employed to assess the normality of residuals. With a JB statistic of **1.862** and a **p-value of 0.394**, the null hypothesis of normal distribution is **not rejected**.
This indicates that the residuals are normally distributed.

7.3.2. No Autocorrelation:

The **Durbin-Watson statistic** was used to check for autocorrelation in residuals. The obtained value of **1.88** lies within the acceptable range of **1.5 to 2.5**, suggesting that **no significant autocorrelation** exists among the residuals.

7.3.3. No Multicollinearity Among Independent Variables (Table 4):

Table 4 – Multicollinearity Diagnostics

Independent Variable	VIF	Tolerance
TAXAVOID	1.26	**0.794**
AUDITQUAL	1.13	**0.885**
SIZE	1.31	**0.763**
LEV	1.18	**0.847**

Based on the table above, since the Variance Inflation Factor (VIF) for all variables is below 5, there is no evidence of multicollinearity among the independent variables. This indicates that the regression coefficients are not distorted due to multicollinearity, and the model estimates can be considered statistically reliable.

7.3.4. Assessment of Homoscedasticity (Variance Uniformity):

The scatterplot of residuals is randomly dispersed around the zero axis. Therefore, homoscedasticity is confirmed. The final research model is statistically significant, and all independent variables have a significant effect on the dependent variable (ROA). The regression coefficients, both in direction and magnitude, are consistent with theoretical expectations. Moreover, the classical statistical assumptions of the regression model are satisfied, ensuring the validity of the statistical inferences drawn from the model.

7.4. Second Regression Model:

$$ROA_{it} = \beta_0 + \beta_1.TAXAVOID_{it} + \beta_2.AUDITQUAL_{it} + \beta_3.SIZE_{it} + \beta_4.LEV_{it} + \varepsilon_{it} \qquad (3)$$

The R^2 value of 49.4% indicates that the independent variables explain nearly half of the variation in ROE. The F-test, with a highly significant p-value (Sig = 0.000), confirms that the overall model is statistically significant. Additionally, the negative and significant coefficient of the tax avoidance variable demonstrates its adverse effect on the return on equity. It is also noteworthy that both firm size and audit quality have positive and significant impacts on ROE, reflecting the advantages of larger firms and high-quality audits in enhancing profitability. Moreover, the debt ratio exhibits a negative effect on ROE, which is justifiable from the financial risk perspective. (Table 5)

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Table 5 – Results of the Multiple Regression Model for ROE

Beta Coefficient (β)	t-Statistic	Significance Level (Sig.)	Statistical Significance	Independent Variable
0.063	1.924	0.05	Significant at the 0.05 level	**Constant**
-0.089	3.721	0.001	Significant	**TAXAVOID**
-0.041	2.114	0.037	Significant	**AUDITQUAL**
0.012	3.688	0.001	Significant	**SIZE**
-0.024	2.641	0.010	Significant	**LEV**
0.494				**R²**
0.481				**Adjusted R²**
	38.502	0.000	Significant	**F-Statistic**
120 Companies				**Number of Observations**

Research Recommendations

Based on the findings of this study, which indicate a significant positive relationship between tax avoidance and corporate financial performance, as well as the moderating role of audit quality in this relationship, it is recommended that company managers engage professional and industry-specialized auditors. This approach can enhance the quality of financial reporting and mitigate the negative consequences of aggressive tax behaviors. Additionally, regulatory bodies, including the Securities and Exchange Organization and the Tax Administration, should design appropriate control and incentive mechanisms given the critical importance of tax avoidance and its impact on corporate performance indicators.

Furthermore, attention to factors such as auditor independence, industry expertise, and auditor rotation frequency can serve as effective policy tools to improve corporate financial health. Finally, future researchers are encouraged to incorporate other moderating variables, such as ownership structure, ownership concentration, and corporate governance, in subsequent studies to develop a more comprehensive understanding of the mechanisms through which tax avoidance affects financial performance.

Conclusion

This study examined the relationship between tax avoidance, audit quality, and financial performance of companies listed on the Tehran Stock Exchange during the period 2018 to 2023. Financial performance was measured using return on assets (ROA) and return on equity (ROE) indicators. Tax avoidance was assessed by the ratio of the difference between accounting tax expense and actual tax paid to pre-tax profit, while audit quality was evaluated using proxy variables such as the type of audit firm and the auditor's tenure.

The statistical findings revealed a significant relationship between tax avoidance and financial performance, indicating that companies with higher levels of tax avoidance on average exhibited better financial performance in terms of increased ROA and ROE. This finding aligns with the theoretical perspective of some prior studies that interpret tax avoidance as a strategy to optimize cash costs and enhance short-term profitability [10]. However, this relationship may have adverse effects on the company's credibility and risk in the long term.

On the other hand, audit quality was also found to have a positive and significant association with financial performance. The results indicated that companies benefiting from higher-quality audits (whether from reputable auditors or with longer auditor tenure) experienced higher levels of return on assets and return on equity. This can be attributed to the role of quality auditors in improving financial information transparency, reducing information asymmetry, and strengthening investor confidence.

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A notable aspect of the findings was the interactive effect of audit quality in moderating the relationship between tax avoidance and financial performance. In other words, in companies with higher audit quality, the positive impact of tax avoidance on financial performance was amplified. This suggests that audit quality can act as an enabler for more effective exploitation of tax strategies while simultaneously preventing potential deviations.

Therefore, it can be concluded that tax avoidance, when conducted within the legal framework and accompanied by professional auditor oversight, can lead to improved financial performance. Furthermore, the mediating role of audit quality in this relationship highlights the importance of policy-making in the supervision of the auditing profession.

Acknowledgments

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Space-time, Dark matter and Dark energy

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ABSTRACT

According to the theory of classical physics, objects exert force on each other, but this theory never says anything about what this force is, why do two objects attract each other? According to the theory of relativity, gravity is not basically defined as a force, but it is the result of the curvature of space-time. This theory, which is used for large-scale objects, seems to be deficient for medium-scale and micro-scale objects.

In this article, we discuss a new definition of space-time and gravity, and by combining two theories of relativity and classical physics, we arrive at new formulas, and from there, by analyzing these formulas and also mathematical analysis, we will present a new definition of space-time and gravity, and even dark matter and dark energy.

This research leads to a new theory and since it is associated with the analysis of the relevant formulas, it will be called analytical theory.

This theory should be able to solve many astronomical topics such as; justify gravity, black holes, dark matter, dark energy, lens effect, the reason for the accelerated movement of objects in gravitational fields, etc. And we will deal with these issues as much as possible in this article and we will complete it in future articles.

Keyword: Space-time, Dark matter, Dark energy, gravity force, analytical theory, space, time

INTRODUCTION

Every mathematical expression has a physical equation in nature and every physical phenomenon in nature has a mathematical equivalent. With this thinking, physical phenomena can be physically analyzed, conceptualized, and then come to the appropriate theory. Finally, in order to ensure the accuracy of the research path and the findings, mathematical analysis is used. Although, in recording the results of the research, first the mathematical analysis is done, then the physical analysis and finally the theory is recorded.

MAIN TEXT:
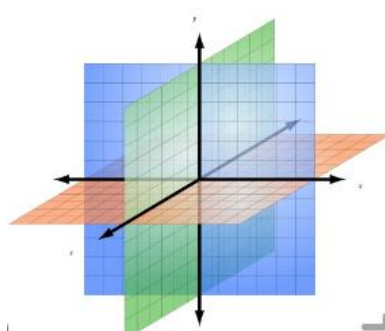
Consider the three-dimensional coordinate axes, the positive directions according to the counterclockwise convention of the three fingers of the left hand will be x, y, z, respectively, and their opposite direction will be -x, -y, -z-. Note that the positive and negative directions of the axes are conventional.

The axis of numbers in which positive real numbers, continue from zero to the right to infinity. according to the convention, and negative numbers continue from zero to the left to negative infinity.

Number axis in points such as one third and one sixth and many other points such as Numbers with infinite decimals and repeating decimals, etc., do not show a specific position on the number axis [1]. At these points, the axis of numbers is interrupted and they approach a limit number from both sides, so the axis of numbers is not a continuous line.

The dimensions of the space on the coordinates axes are also interrupted at these points, and on the x, y, z axes they form the units that form the cells that make up the texture of the space, and this means that the space is quantum and its texture consists of Units and cells are formed.

With a 180degrees rotation and against the direction of positive real numbers, we will have negative real numbers (-1, -2 and ...).

Imagine that the negative semi-axis of numbers is a ruler and a measuring scale. If we have a ruler of unit length and pull it on the negative semi-axis, its length will go from -1 to -2, and then it will be observed Elongation decreases from -1 to -2 due to stretching.

Our baryonic universe is flowing on a bed of space-time.

Now let's analysis the dimensions of space-time:

The baryonic world has three positive dimensions of space, which correspond one to one, to the positive part of the coordinate axis (x, y, z). And it forms the skeleton of the contents of the baryonic universe.

In the mathematical analysis, it was observed that the axis of numbers continues from zero to positive infinity and from the other side to negative infinity. In the Cartesian coordinate axes, the three axes x, y, z, continue towards the positive infinity and from another direction from the Coordinate origin of the mentioned three axes to the negative infinity.

It is also seen in the dimensions of space that the three dimensions x, y, z, form the three dimensions of space, and with the dimension of time we reach the four dimensions of space-time. Note that for ease of understanding and related mathematical calculations, we consider the directions to be conventionally positive directions of three dimensions of space-time. For example, we may use the left hand rotation rule to determine the positive directions of x, y, z dimensions. Be careful that these directions are conventional and in practice these dimensions can be expanded in any direction.

Now this question arises, so what will happen to the negative direction of the triple axes of the space dimensions?

This is while in the current science of physics for the baryonic world, only 3 dimensions of space are imagined, which form the skeleton of the baryonic world. With the similarity that can be observed between the characteristics of the negative part of the Cartesian coordinate axes or the number axis and the dimensions of space, we can reach interesting results, and that is that *space corresponds to the negative dimension of the coordinate axis*, that is, it reveals other dimensions of the universe and those dimensions The negative is space.

It seems that the space is composed of three negative dimensions, which itself is the origin of the positive three dimensions of the baryonic world, and in addition, it is like an eschel and the scale of the formation of the positive three dimensions (baryonic world), in other words, the positive dimensions of space-time. Without the negative dimensions of space, which will be called the second three dimensions of space-time from now on, it cannot be formed because the world loses its presence.

Secondly, these are the second three dimensions of the universe that determine the *dimensions* and *size of the objects* and even the particles that make up the first three dimensions.

In the mathematical analysis, we also saw that if, for example, If we pull the rubber band on the negative coordinate axes, its length decreases from -1 to, for example, negative 2. This also happens in reality.

If you pull the dimensions of space (the second three dimensions) in the first three dimensions, we will have the contraction of the length (in the same direction) and of course due to the interweaving of space and time, with the expansion of the length of the space (the second three dimensions of the space), the expansion of time will also occur.

In a separate article, we will discuss the mathematical analysis of *time dilation*.

gravity:

According to the theory of classical physics, gravity is the force that two masses exert on each other, but this theory never says anything about what this force is. (Why do two masses attract each other?).

According to the theory of relativity, gravity is not fundamentally defined as a force, but rather a result of the curvature of space-time. This theory, which is used for large-scale objects, seems to be deficient for medium-scale and micro-scale objects. If the first three dimensions of space constitute the ossification of the contents of the baryonic universe, we should be able to have a theory combining classical and relativity physics.

It seems that the presence of energy and matter causes a change in the shape and dimensions of space so that energy and matter tend to be pushed towards a point that we call the singularity point and they are compressed towards it. This singularity, which is conceivable for any collection of energy or matter, is the point where space tries to compress matter and energy into it. Space exerts a force on mass or energy to concentrate it at a singularity point, so, this force is expected to be calculable.

The presence of mass (or energy equivalent to mass) causes a change in the Texture of space-time and stores potential energy in it, which eventually enters any mass in the gravitational field and pushes it towards the singularity point.
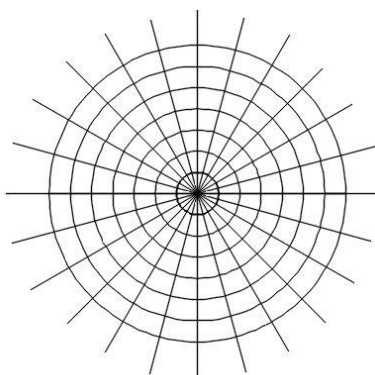
The mass-equivalent energy that changes the texture of space is equal to $E = m_1 C^2$

And the stored potential energy in the deformed tissue (according to the classical theory) will be equal to: $E = m.g.x$ where x is the radius of the gravity field (distance from the singularity point) in the second three dimensions of the space where the mass m is present in its bed.

$$E = m\left(G\frac{m}{x^2}\right)x$$

From equality, we will have two recent relations:

$$m_1 C^2 = m\left(G\frac{m}{x^2}\right)x \quad \Longrightarrow \quad X\,C^2 = \left(\frac{m^2}{m_1}\right)G \quad , \quad M = \frac{m^2}{m_1}$$

(M is the equivalent mass of the system)

$$\alpha = \left(\frac{c^2}{G}\right)$$ α is constant value and G is the global constant of gravity

As a result, we will have: $g\,x = c^2$ and $M = \alpha\,x$

Analysis of the above formulas:

1- The formula $m = \alpha\,x$ clearly speaks of the equivalence of M and x, in other words, M and x are of the same type, and since energy and mass are equivalent, it can be concluded that the dimension and energy are also the same. The dimensions of space are also of energy and the result of energy.

2- The dimensions of the texture of space are symmetrical in the natural state and will be in the form of a spherical shell, which is also quantized according to the aforementioned cases, and stretching in one direction causes the force and acceleration of the mass in the same direction and towards the singularity point.

The flow of energy or its equivalent mass is on the surface of the tissue sphere. And inside the spherical shell is dimensionless. The absence of dimension inside the spherical shell means that if the mass and energy have a dimension smaller than the value of the minimum dimension of space (space quantum), the movement in it will be instantaneous.

But since the dimensions of matter and energy packages are defined by the quantum dimensions of space, the dimensions of matter cannot be smaller than the quantum dimensions of space, and probably at least the dimension of space is equal to the Planck length.

If the quantum of the spherical shell of space is stretched in one direction, for example, by the size of dx, the mass and energy in that direction can have an instantaneous displacement by the size of *dx*.

3-The value of g is the closer to the center of the singularity point, which means that the dimension of space near the singularity point has more elongation, and the further away from it, the amount of space elongation will be less, this causes the body that is under the singularity force to move towards the singularity point. move and because the amount of lateral elongation increases as we move towards the singularity point, the instantaneous displacement towards the singularity point also increases and causes the mass to accelerate, and the movement of the mass towards the singularity point will be an accelerated movement.

4-The Formula $M = \alpha\,x$ indicates that the presence of *M* will cause the stretching of the space dimension, and conversely, the stretching of the space dimension will cause the mass of *M*. Therefore, if for any reason the stretching of the dimension of space happens, this will cause the creation of mass in the dimension of the space under stretching.

This means that the space itself has a hidden mass, which is probably the same dark matter, that is, the presence of large objects such as planets and stars and, accordingly, galaxies causes the stretching of the dimensions of the space, which is also of energy, and in the range of Radius affected by the gravitational force. a mass appears that forms the same dark matter and it seems that dark energy is the same energy that forms space.

Each particle (mass) and energy has its own singularity point, and the objects next to each other will have a resultant singularity point, so that all the objects are pushed towards that singularity point or may go around it.

Depending on the mass of the objects, the singularity point may be somewhere inside one of the objects, such as the solar system, which is inside the sun and close to the center of the sun due to the huge mass of the sun compared to the planets that revolve around it.

Or it may be somewhere outside of the objects, planets and stars, in which case the planets and stars revolve around that singularity.

If the mass of the planets and stars that revolve around the singularity point is very, very large, and it may cause a very, very large stretching of the dimensions of space, then that singularity point will have the third type of stretching (stretching in three dimensions), which is called the swollen phenomenon, all three dimensions of the object are contracted in the first three dimensions and the object falls into the three-dimensional bubble of the space dimension and creates the black hole phenomenon. In the swollen phenomenon, *X* in the related formula that was mentioned earlier is to the power of 3, and the gravity in it increases tremendously and turns into a black hole.

In the swollen phenomenon, which is the expansion of the dimensions of the space, in three dimensions, we will have the stretching of the space dimension of the *second type* (stretching in two dimensions). In other words, the space tissue pulls other cells that are woven into it on its surface and causes the second type of stretching (surface stretching). Outside the cell bubble, we will see cells stretched in two dimensions. The *second type* of drag (*superficial*) will cause objects to move around and around the entangled cell at a very high speed due to its high stretch (for example, in black holes).

First: It will cause the movement of the objects upon entering the accumulative cell and around it. In this situation, it is expected to even cause the cell or black hole to rotate around itself.

Secondly, the body that approaches the black hole, not because of the very strong gravity of the black hole, but because of the two-dimensional stretching of the texture of the space around the black hole   They undergo length contraction in two dimensions (the same term as becoming spaghetti).

The rotation of the stars and planets of the galaxies often have such conditions, and their singularity turns into giant holes, and often the center of the rotation of the galaxies has such condition.

Stretching of the texture of space (second three dimensions of space) while causing the expansion of space, also causes the contraction of length and expansion of time.

Gravity is the result of applying the potential force (the result of the effect of mass (the first three dimensions) on space) on objects that tries to concentrate them in a singularity point, which is due to the stretching of the texture of space due to the presence of energy in the 6 dimensions of space and confusion. It is intertwined with our time dimension.

The singularity point for objects, if it is the result of very massive objects, it may lead to the creation of a black hole in the heart of celestial objects or in a point outside them, which is generally the center of rotation of stars and galaxies around it due to the great force of its singularity. . Sometimes the orbit of planets or stars may be an ellipse, in which case the two foci of the ellipse are singular points and are the source of gravity.

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The Impact of Artificial Intelligence on the Future of Psychology

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Abstract
Psychology, as the science of understanding and examining human behavior and mind, is extensively involved in every individual's life. Compared to other disciplines that pertain to specific aspects of human life, psychology influences and is involved in almost all dimensions of human life and psyche. Meanwhile, the expansion of artificial intelligence and computational minds, which has become more prominent in recent years, has transformed the role of psychology in human life. The process of analyzing and evaluating psychological tests is now conducted with high speed and precision, and access to psychological solutions for addressing life's challenges is facilitated through artificial intelligence, without time or place restrictions, and in the shortest possible time. This study examines the impact of artificial intelligence on the future of psychology, a significant and thought-provoking topic, to determine whether the influence, expansion, and penetration of computational minds in the field of psychology and its future will benefit psychologists and humanity or not.
Keywords: psychology, artificial intelligence, human life, behavior, cognition

Introduction

Psychology, as a discipline that examines human behavior, cognition, and emotions, has made remarkable progress in recent years. Psychology focuses on understanding and analyzing the human mind; yet, it is a science that has always faced limitations in fully mastering the understanding of the mind. Until a few years ago, if someone claimed that computers could think and act like humans in the future, it might have seemed impossible and fantastical. However, in 2025, computers equipped with artificial intelligence can perform these tasks just like humans (Golnama, 2024).

Artificial intelligence is one of the most promising technologies capable of revolutionizing the process of learning and personal development. Currently, many companies have taken action and, through investments in this field, aim to maximize the use of artificial intelligence. Artificial intelligence not only enhances learning but also improves efficiency, interaction, and recall; therefore, utilizing this technology to accelerate and increase the productivity of the learning process is essential (Masoumi & Rajabi, 2024).

The world is witnessing new technological advancements that significantly impact organizations across various sectors. Artificial intelligence is one such advancement that has widely been recognized as a revolutionary technology in various scientific fields, including human resource management, transforming a wide range of human resource management practices (Bahrami Dehdar, 2024).

Artificial intelligence, in essence, is a simulation of human intelligence for computers. It refers to a machine programmed to think like a human and capable of mimicking human behavior. The birth of artificial intelligence occurred between 1950 and 1956, a period when interest in artificial intelligence peaked. During this time, an individual named Alan Mathison Turing published his work titled *Computing Machinery and Intelligence*, which eventually led to the Turing Test, used by experts to measure computational intelligence. In today's world, technological advancements are one of the fundamental factors shaping societal transformations across economic, cultural, political, and social domains (Hosseinpour & Golestannejad, 2024).

The emergence of modern communication technologies in the current era, along with transformations in virtual spaces, has disrupted many family functions. In discussions on the pathology of the family institution, one critical axis is examining the harms resulting from family transformations. Since the internet entered human life, it has imposed certain concerns on families. This issue is relevant across all societies and is not limited to a specific community or minority. Due to the unique characteristics of virtual spaces and their novelty, many parents have not had sufficient opportunities to thoroughly understand this space and its applications. Their lack of familiarity with this space, contrasted with the daily use of it by teenagers, young adults, and even children, has created a confidential and private space within homes for children. They access various websites in this space without concern, and, due to their age, personality traits, and curiosity, they may be influenced by unhealthy environments present on the internet (Zandi et al., 2024).

Given recent advancements in machine learning technologies and algorithms, this technology can significantly contribute to diagnosis, treatment, and psychological research. Among the significant applications of artificial intelligence in psychology are improving the accuracy of diagnosing mental disorders, developing personalized treatment methods, and extensively analyzing psychological data. Artificial intelligence algorithms can identify hidden patterns in large datasets and analyze human behaviors and trends with high accuracy and speed. These capabilities assist psychologists and physicians in making more precise diagnoses and treatment decisions and offering more appropriate intervention strategies. Additionally, artificial intelligence can analyze data automatically and in real-time, contributing to a better understanding of high-risk behaviors and providing effective solutions for improving societal mental health (Ardebili & Rostami, 2024).

Given the expansion of artificial intelligence in all scientific fields and aspects of life, examining whether artificial intelligence will function as a therapist in the future is a topic worth discussing. Considering the complexity of the human psyche and the need for direct empathy and mutual understanding, artificial intelligence may be effective in some cases. However, in addressing challenges that require continuous connection and mutual empathy, it may not have a significant direct impact. Therefore, based on artificial intelligence's specific algorithms, it can be utilized in analyzing intelligence tests, providing greater assistance to individuals compared to before, and other applications. However, care must be taken not to limit the vast science of psychology to artificial intelligence.

Method

The impact and significance of artificial intelligence are evident today in all fields, disciplines, and aspects of human life. With the world's daily progress, the influence of artificial intelligence becomes even more pronounced, a topic that warrants reflection due to its advantages and disadvantages that will shape the future of various disciplines. Artificial intelligence has sparked a revolution worldwide and in all systems, including psychology. What artificial intelligence accomplishes in a short time today—results obtained through artificial intelligence or, in other words, computational minds—were either unattainable through traditional methods in the past or extremely time-consuming (Golnama, 2024).

Psychology, as a complex science that studies human behavior, mind, and psyche, is among the disciplines where the impact of artificial intelligence is entirely evident, creating significant changes in this field. With the advancement of artificial intelligence, some robots and websites will respond to human life's challenges in place of a psychologist. In the past, psychologists had to spend hours analyzing formulas derived from evaluating the human mind and psyche. However, today, thanks to complex artificial intelligence algorithms, this task is performed in less time and with more precise information (Ardebili & Rostami, 2024).

Humans, due to their inherent altruism and empathy, always need to feel understood by others. In this regard, artificial intelligence cannot have as much impact as a human. By reflecting content and emotions, humans can address some personal life challenges even without reaching a solution to those challenges. In a study conducted through oral interviews with recently married women, the result was that they felt better when expressing their life challenges to another person rather than finding a solution through artificial intelligence. Of course, it must be noted that sometimes the goal of expressing life challenges is not merely to resolve them but rather to feel calm and psychologically at ease before addressing the issue with greater focus and tranquility to find a solution.

Given the global expansion of artificial intelligence, cultural differences are not considered when addressing human psychological challenges. However, with the rapid advancement of artificial intelligence, there is hope that in the future, this issue will be fully addressed by artificial intelligence to establish continuous communication with humans from different cultures (Hosseinpour & Golestannejad, 2024).

Diagnosing Depression Related to Humans Using Artificial Intelligence Tools

Depression affects specific parts of the brain. Research has shown that the brain regions impacted by depression are highly similar across individuals. Therefore, by examining these brain structures in MRI scans, we can predict with over 80% accuracy whether an individual has depression. Other studies using advanced artificial intelligence models support this finding, indicating that brain structure can be a useful tool for artificial intelligence-based diagnosis. Studies using MRI imaging data on brain function during rest can also correctly predict depression in over 80% of cases. However, combining functional and structural MRI information yields the highest accuracy, correctly predicting depression in over 93% of cases. This suggests that using multiple brain imaging techniques for artificial intelligence in diagnosing depression may be the most effective way forward.

Currently, MRI-based artificial intelligence tools are used solely for research purposes. However, as MRI scans become cheaper, faster, and more accessible, this technology will likely soon become part of a physician's toolkit, aiding in improving diagnosis and enhancing patient care. Depression is one of the common disorders in today's societies, manifesting in varying degrees of severity. If diagnosed in its early stages, it can be treated easily with less time and cost. In this study, using data from various personality tests labeled by a certified expert, obtained

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from a statistical population of clients in Shiraz, we aim to select a model for predicting depression in clients using classification algorithms. In this research, the data obtained from clients is first preprocessed, then applied to several classification algorithms using the Weka data mining software, and the results are compared based on the cross-validation method (Sokaki & Goodarzi, 2024).

Research Method

This article utilized a documentary research method, referencing books, journals, and related scientific websites, along with note-taking and index card preparation, to reach the research findings and article conclusions.

Research Questions

1. To what extent can computational minds (artificial intelligence) be effective in psychology?
2. What are the advantages of artificial intelligence in the future of psychology?
3. What are the disadvantages of artificial intelligence in the future of psychology?
4. What should be done to mitigate the impact of the disadvantages of artificial intelligence in psychology?

Discussion and Conclusion

Given the vast expansion of computational minds, which we now refer to as artificial intelligence, a revolution has occurred in all scientific and social aspects of humanity. The impact of artificial intelligence is so profound that it is referred to as a revolution. Like anything else, artificial intelligence naturally has both advantages and disadvantages.

In terms of progress in addressing human psychological challenges, we highlight its advantages, while in terms of failing to meet certain nuanced psychological needs, we note its disadvantages. With the rapid advancement of science and technology, artificial intelligence will have an even more prominent presence and impact on human life in the future, potentially replacing humans in some disciplines (Golnama, 2024; Ardebili & Rostami, 2024).

The issues raised regarding artificial intelligence in each discipline are currently under review to maximize its use in accelerating human life processes and addressing issues related to the psyche, social life, and all aspects of human existence.

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The Relationship Between Teachers Professional Skills and Students Academic Procrastination in Elementary Schools

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ABSTRACT

The aim of this study is to examine the relationship between teachers' professional skills and academic procrastination among elementary school students in the city of Pakdasht.

This research is applied in terms of purpose and correlational-descriptive in terms of method. The statistical population includes 454 teachers working in elementary schools, from which 80 teachers were selected using simple random sampling.

Data collection was carried out using two standard questionnaires: the Professional Skills Questionnaire by Varizk (2001) and the Academic Procrastination Questionnaire by Solomon and Rothblum (1984).

After data collection, the information was analyzed using SPSS software through descriptive statistics (mean and standard deviation) and inferential statistics (Pearson correlation test).

The results showed a significant inverse correlation between teachers' professional skills and students' academic procrastination. Furthermore, all dimensions of professional skills—including process skills, content-based skills, system-related skills, problem-solving skills, social skills, resource management skills, and technical skills—had a significant negative relationship with students' academic procrastination.

Keywords: Job skills, procrastination, teachers, job skills, academic procrastination

INTRODUCTION

The term procrastination is derived from the Latin words pro (meaning "forward" or "in favor of") and crastinus (meaning "of tomorrow"), conveying the idea of delaying or postponing actions. It is often synonymous with neglect, delay, and hesitation. Many individuals suffer from procrastination, which almost always has negative effects on productivity and overall well-being. Although everyone procrastinates in their own way, one widely accepted definition describes it as the unnecessary delay in completing tasks without a valid reason [20].

Procrastination influences various aspects of life and can lead to significant consequences, including poor academic performance, lower grades, lack of class participation, dependency, fear of failure, aversion to tasks, negative self-evaluation, low self-esteem, learned helplessness, avoidance-oriented goal setting, and feelings of inferiority [12].

Specifically, various studies argue that teachers are uniquely positioned to influence students' academic procrastination. For instance, Steel et al. (2022) suggested that teachers can significantly reduce students' academic procrastination by fostering a positive and empowering classroom environment. Similarly, Codina et al. (2020) concluded that supportive and controlling teaching styles play a key role in this regard. A supportive teaching style can meet students' psychological needs and reduce procrastination, while controlling approaches tend to increase it.

One of the most influential institutions in shaping the personality of adolescents and young people is the school. After the family, the school plays the most important role in the process of socializing adolescents. Through teaching scientific and technical skills and creating opportunities for group cooperation and responsibility, the school contributes to the holistic and balanced development of students' personalities [6]. Furthermore, when teachers possess not only knowledge but also sufficient professional skills, the educational system will undoubtedly become more effective, efficient, and credible [2].

2

Given the critical role of teachers in shaping students' academic behaviors, this study aims to explore the relationship between teachers' professional skills and academic procrastination among students. The central question guiding this research is: What is the relationship between teachers' professional skills and students' academic procrastination?

2. Theory and Literature Review

Job Skills: In order for an organization to achieve its goals, employees must perform their tasks at a satisfactory level of efficiency. This issue is critical for public organizations, whose poor performance leads to failure in delivering public services, as well as for private companies, where weak performance can lead to bankruptcy. From a social perspective, the most interesting aspect for organizations is to have employees who perform their work well. Good skills increase organizational productivity, ultimately leading to an increase in the national economy. Job skill is a composite construct in which successful employees are defined by a set of specific behaviors. Therefore, job performance is a multidimensional and broad criterion, in which a combination of well-defined behaviors is used to express it [1].

Soft Skills: Job skills can be broadly classified into soft skills and hard skills. Due to the widespread use of technology in many tasks, soft skills have gained even more importance. Soft skills refer to personal traits and intellectual growth that are essential for an individual. These skills are not typically taught in academic institutions and must be developed personally through study and practice. Some of these skills required for employment in any job include creativity, persuasion, teamwork, adaptability, time management, high public relations, teamwork abilities, problem-solving skills, etc. [8].

Hard Skills: Hard skills refer to technical skills that individuals acquire either through academic education or practical experience. Below are some examples of skills that are currently highly sought after in the job market, based on societal needs and statistics:

Technical and Vocational Skills: The expansion of technology in various fields has increased the market demand for technical skills. Specialists with skills in installation, testing, and repair in fields such as mechanical, electrical, communications, transportation, etc., are always in demand in the job market [4].

Computer Skills: Proficiency in programming languages opens up many job opportunities. Languages like HTML, C++, Java, etc., can provide suitable employment opportunities when mastered [11].

Teaching Skills: In today's world, where vast amounts of information are produced, collected, and consumed daily, people seek to learn more in various fields. If you have expertise in a particular area, you can easily secure a job in education and ensure the quality of your life [10].

Financial Management Skills: The ability to plan economically to ensure a comfortable life is essential. Brokers, financial planners, accountants, and auditors will always find job opportunities based on this societal need [7].

Job Skills Needed by Teachers Today:

Commitment, Expertise, and Professional Conscience: One of the essential characteristics in any job, especially teaching, is having commitment, expertise, and professional conscience. A teacher must have the necessary expertise in their field of study. Additionally, professional conscience significantly impacts the teacher's performance [14].

Familiarity with Information Technology and Computer Science: In the 21st century, it is no exaggeration to call someone who lacks computer knowledge illiterate. All teachers must be fully familiar with computer science and the information technology prevalent in society. Every teacher should have a personal computer at home with internet access to keep up with the latest scientific information, advancements, and professional needs [15].

Study and Research Skills: Another essential skill for teachers in the knowledge age is research ability. Teachers should allocate time for study and research alongside their regular duties [19].

Awareness of Global Changes: A key feature of modern teachers is having deep political and intellectual insight. Teachers today must be familiar with political and economic transformations worldwide [3].

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Physical and Mental Health: With the advancement of industries, technology, and industrialization, modern life has brought along undesirable gifts such as environmental pollution, noise pollution, anxiety, stress, depression, and tension. A teacher must live in conditions where they maintain good physical and mental health. If a teacher is preoccupied with their personal life when in class, they won't be able to perform effectively. Therefore, authorities must address teachers' concerns about their living conditions [17].

Familiarity with New Psychological Theories: With the advancement of other sciences, psychology has undergone significant transformations. A teacher today, due to working with children and adolescents, must be familiar with the latest psychological theories for children and adolescents. Teaching should incorporate modern and effective psychological methods [9].

Application of Modern Teaching Methods: As teaching methods play a crucial role in instructional design, the teacher of today must be familiar with the latest teaching methods. Traditional teacher-centered classrooms no longer meet the active and inquisitive minds of today's students. Our educational approach must shift towards student-centered classes with active and dynamic teaching methods. Therefore, it is crucial to engage students in the educational and developmental activities to enhance learning [9].

Procrastination: The Latin word for procrastination, "procrastinatio," consists of two parts: "pro," meaning "forward," and "cras," meaning "tomorrow" (Ferrari et al., 1995). The Cambridge Dictionary (2003) defines procrastination as the act of delaying something because it is unpleasant or tedious. In another definition, procrastination is the act of postponing a task, particularly when the delay is without a valid reason. Ellis and Knaus (1997) define procrastination as the tendency to avoid an activity, postpone its completion, and use excuses to justify the delay in performing a task. This definition highlights laziness and putting off important tasks at expected times, often accompanied by uncomfortable mental experiences [20].

Levels of Procrastination: The phenomenon of procrastination involves both cognitive and behavioral levels. Behaviorally, an individual fails to complete a task they intended to do without any specific reason and voluntarily misses the designated time. On the cognitive level, the person delays decision-making. Most people, when they hear the term procrastination, imagine avoiding assigned tasks, daily chores, or homework. For example, a person watching television or taking a nap instead of doing their task is engaging in behavioral procrastination. Another form of procrastination, which is often linked to anxiety and remains hidden, is decision-making procrastination, which can be very damaging. Procrastination in decision-making occurs when one postpones making a decision. Examples include hesitating when buying an item or choosing between yellow and gray for your bedroom color [25].

Domestic Research Background

Momeni and Zohour Parvaneh (2021) in a study titled The Relationship between Classroom Psychological-Social Climate and Academic Procrastination among Students: The Mediating Role of Perceived Stress aimed to examine the relationship between the classroom psychological-social climate and academic procrastination. They concluded that increasing a positive classroom psychological-social environment reduces perceived stress and academic procrastination among students.

Zarei and Ajami (2020) in a study titled Investigating the Relationship Between Elementary Teachers' Curriculum Planning Skills and Academic Procrastination and Academic Enthusiasm (Study of Elementary Teachers in District 19 of Tehran) aimed to examine the relationship between teachers' curriculum planning skills and academic procrastination and enthusiasm. They concluded that there is a significant negative relationship between teachers' curriculum planning skills and academic procrastination and a significant positive relationship with students' academic enthusiasm.

Ranjbar and Bayanfar (2019) in a study titled The Relationship Between Teachers' Personality Traits and Responsibility with Procrastination and Academic Achievement Motivation among Students aimed to examine the relationship between teachers' personality traits and responsibility with procrastination and academic achievement motivation among students. They concluded that there is a significant negative relationship between teachers' personality traits (extroversion, flexibility, agreeableness, conscientiousness) and students' procrastination, and a significant positive relationship with students' academic achievement motivation. Additionally, there was a significant positive relationship between teachers' personality trait (neuroticism) and students' procrastination and a significant

negative relationship with students' academic achievement motivation. The study also showed a significant relationship between teachers' responsibility with both academic achievement motivation and students' procrastination.

Monadi and Esmaeili (2016) in a study titled Identifying the Causes of Academic Procrastination from the Perspective of Female High School Students aimed to explain the causes of academic procrastination from the perspective of female high school students. They found that the main themes of academic procrastination causes among high school students include the role of parents and monitoring homework, school attendance hours, teaching methods, intrinsic motivation, communication skills, and emotional intelligence.

Foreign Research Background

Steel et al. (2022) in a study titled The Role of Teaching Methods in Student Procrastination aimed to examine the impact of teaching methods on student procrastination. They concluded that teachers can significantly reduce academic procrastination by creating a positive and empowering environment.

Li (2021) in a study titled Predicting Academic Procrastination Based on Academic Performance and Classroom Psychological-Social Climate in Students aimed to predict academic procrastination based on students' academic performance and classroom psychological-social climate. They concluded that the classroom psychological-social climate can be a good predictor of academic procrastination in students.

Koudina et al. (2020) in a study titled Preventing Procrastination Behaviors: Teaching Styles and Competencies in University Students aimed to examine the relationship between students' perceptions of teachers' teaching styles, satisfaction of competency needs, and procrastination behaviors. They found that supportive and controlling teaching styles significantly impact student procrastination. A supportive teaching style can meet students' psychological needs and reduce procrastination, while controlling styles increase procrastination.

Akbay and Gozar (2020) in a study titled Factors Influencing Academic Procrastination Among Students: A Case Study aimed to investigate the factors influencing academic procrastination among students. They concluded that teachers' time management skills and the use of motivational techniques reduce procrastination. Additionally, fear of failure and fear of evaluation are factors that increase procrastination.

3. Materials and Methods

Research Method: This study is applied in terms of purpose, descriptive-correlational in terms of data collection method, and quantitative in terms of data type. The research was conducted using a questionnaire-based approach.

Statistical Population: The statistical population consisted of 454 elementary school teachers employed in schools across Pakdasht County.

Sample and Sampling Method: Using Cochran's formula and simple random sampling, a total of 80 teachers were selected as the study sample.

Data Collection Tools: Data for this study were collected through two methods:

Library Research: In this method, information related to the theoretical framework and research background was gathered using books, theses, articles, and academic databases.

Field Research: In this stage, two standardized questionnaires were distributed among the sample to collect the required data:

Varizk's Job Skills Questionnaire (2001): This questionnaire includes 25 items rated on a five-point Likert scale ranging from "very high" to "very low". It evaluates various dimensions of teachers' job skills, including process skills, content-based skills, system-related skills, problem-solving skills, social skills, resource management skills, and technical skills.

Solomon and Rothblum's Academic Procrastination Questionnaire (1984): This instrument consists of 27 items covering three main components: exam preparation (8 items), assignment preparation (11 items), and end-of-term preparation (8 items). Each item is rated on a five-point Likert scale from "never" (score 1) to "always" (score 5).

Validity and Reliability of the Instruments:

a) Job Skills Questionnaire:
This questionnaire is a translated version of a standardized instrument originally developed by Varizk (2001) and translated into Persian by Moghimi and Ramazan (2011). Since its validity and reliability had not been previously assessed in Iran, the translated version was reviewed by several experts and educators in the field. Based on their feedback, revisions were made to enhance the clarity and relevance of the items, particularly in the context of teachers' job skills. As a result, the content validity of the instrument was confirmed. The reliability, assessed via Cronbach's alpha, was 0.89, indicating high internal consistency.

b) Academic Procrastination Questionnaire:
Due to its widespread use at both national and international levels, the face and content validity of this standard questionnaire are well-established. In a previous study by Hajizadeh (2011), its reliability was reported as 0.81 using Cronbach's alpha. In the present study, the reliability was calculated to be 0.87, demonstrating good internal consistency.

Data Analysis Method:
Data were analyzed using both descriptive and inferential statistics. Descriptive statistics included frequency tables and measures of central tendency and dispersion. For inferential analysis, the Kolmogorov–Smirnov test was used to examine the normality of the data distribution, and Pearson's correlation coefficient was employed to investigate the relationships between the study variables. Data analysis was performed using SPSS software.

4. Discussion and Conclusion
Assessment of the Normality of Variable Distributions:
To evaluate the normality of the variables, the Kolmogorov–Smirnov test was employed. The results are presented in Table 4-6. As shown, the significance level for all dimensions was greater than 0.05. Therefore, it can be concluded that the distribution of scores for the variables is normal, and parametric tests were accordingly used for further analysis.

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Table 4-6: Results of the Kolmogorov–Smirnov Test

		Teachers' Job Skills	Process Skills	Content-Oriented Skills	System-Related Skills	Problem-Solving Skills	Social Skills	Resource Management Skills	Technical Skills	Students' Academic Procrastination
Count		80	80	80	80	80	80	80	80	80
Parameters of the normal distribution	Mean	96.4875	17.1750	14.9750	11.6125	12.2625	14.4125	12.7625	15.4125	60.7000
	Standard deviation	28.03930	20.06999	5.47717	3.24718	4.43446	4.56651	4.32609	4.96237	17.15706
Maximum range of data	Conclusive	.234	.387	.194	.222	.144	.214	.163	.200	.176
	Positive	.131	.387	.129	.148	.144	.108	.089	.103	.130
	Negative	-.234	-.244	-.194	-.222	-.114	-.214	-.163	-.200	-.176
statistic		.234	.387	.194	.222	.144	.214	.163	.200	.176
Significance level		.0٨0c	.0٩٤c	.٢00c	.0٦0c	.0٧٩c	.٢00c	.0٨٣c	.١٣0c	.0٧٥c

Main Hypothesis Test

There is a relationship between teachers' professional skills and academic procrastination in elementary students in Pakdasht city.

To test this hypothesis, Pearson's correlation test was used. The results obtained, which are presented in Table ۷-۴, show that the correlation coefficient between teachers' professional skills and academic procrastination in elementary students in Pakdasht is -۰/۵۳۵ at a significance level close to ۰/۰۰۰. This indicates that there is an inverse relationship between teachers' professional skills and academic procrastination in elementary students in Pakdasht. In other words, the test of this hypothesis reveals that as teachers' professional skills improve, the level of academic procrastination among their students decreases.

Table 4-7: Pearson Correlation Test Results for the Main Hypothesis

		Teachers' professional skills	Academic procrastination of students
"Teachers' professional skills"	Pearson's statistic	1	-.535**
	Significance statistic		.000
	Sample size	80	80
Student academic procrastination	Pearson's statistic	-.535**	1
	Significance statistic	.000	
	Sample size	80	80

Secondary Hypothesis

Sub-hypothesis 1: There is a relationship between teachers' process skills and academic procrastination among elementary school students in Pakdasht County.
To test this hypothesis, Pearson's correlation test was used. The results, presented in Table 8-4, indicate that the correlation coefficient between teachers' process skills and academic procrastination among elementary school students in Pakdasht County is -0.303, with a significance level close to 0.000. This means that there is an inverse relationship between teachers' process skills and academic procrastination among elementary school students in Pakdasht County. In other words, the results of testing this hypothesis show that as teachers' process skills improve, the level of academic procrastination among their students decreases.

Table 4-8: Results of Pearson's Test for Sub-hypothesis 1

		Academic procrastination of students	Teachers' process skills
Academic procrastination of students	Pearson's statistic	1	-.303**
	Significance statistic		.006
	Sample size	80	80
Teachers' process skills	Pearson's statistic	-.303**	1
	Significance statistic	.006	
	Sample size	80	80

Sub-hypothesis 2: There is a relationship between teachers' content-related skills and academic procrastination among elementary school students in Pakdasht County. To test this hypothesis, Pearson's correlation test was used. The results, presented in Table 4-9, indicate that the correlation coefficient between teachers' content-related skills and academic procrastination among elementary school students in Pakdasht County is -0.362, with a significance level close to 0.000. This means that there is an inverse relationship between teachers' content-related skills and academic procrastination among elementary school students in Pakdasht County. In other words, the results of testing this hypothesis show that as teachers' content-related skills improve, the level of academic procrastination among their students decreases.

Table 4-9: Results of Pearson's Test for Sub-hypothesis 2

		Academic procrastination of students	Teachers' content-related skills
Academic procrastination of students	Pearson's statistic	1	-.362**
	Significance statistic		.001
	Sample size	80	80
Teachers' content-related skills	Pearson's statistic	-.362**	1
	Significance statistic	.001	
	Sample size	80	80

Sub-hypothesis 3: There is a relationship between teachers' system-related skills and academic procrastination among elementary school students in Pakdasht County. To test this hypothesis, Pearson's correlation test was used. The results, presented in Table 10-4, indicate that the correlation coefficient between teachers' system-related skills and academic procrastination among elementary school students in Pakdasht County is -0.577, with a significance level close to 0.000. This means that there is an inverse relationship between teachers' system-related skills and academic procrastination among elementary school students in Pakdasht County. In other words, the results of testing this hypothesis show that as teachers' system-related skills improve, the level of academic procrastination among their students decreases.

Table 4-10: Results of Pearson's Test for Sub-hypothesis 3

		Academic procrastination of students	Teachers' system-related skills
Academic procrastination of students	Pearson's statistic	1	-.577**
	Significance statistic		.000
	Sample size	80	80
Teachers' system-related skills	Pearson's statistic	-.577**	1
	Significance statistic	.000	
	Sample size	80	80

Sub-Hypothesis 4: There is a relationship between teachers' problem-solving skills and academic procrastination of elementary students in Pakdasht.

To test this hypothesis, the Pearson correlation test was used. The results, presented in Table 11-4, indicate that the correlation coefficient between teachers' problem-solving skills and academic procrastination of elementary students in Pakdasht is -0.736, which is statistically significant at a level close to 0.000. This means that there is an inverse relationship between teachers' problem-solving skills and academic procrastination of elementary students in Pakdasht. In other words, the results of this hypothesis testing showed that as teachers' problem-solving skills improve, the level of academic procrastination among their students decreases.

Table 4-11: Pearson Correlation Test Results for Sub-Hypothesis 4

		Academic procrastination of students	Teachers' Problem-Solving Skills
Academic procrastination of students	Pearson's statistic	1	-.736**
	Significance statistic		.000
	Sample size	80	80
Teachers' Problem-Solving Skills	Pearson's statistic	-.736**	1
	Significance statistic	.000	
	Sample size	80	80

Sub-hypothesis 5: There is a relationship between teachers' social skills and academic procrastination of elementary students in Pakdasht County.

To examine this hypothesis, the Pearson correlation test was used. The results, presented in Table 12-4, indicate that the correlation coefficient between teachers' social skills and academic procrastination of elementary students in Pakdasht County is -0.177, with a significance level close to 0.000. This suggests that there is an inverse relationship between teachers' social skills and academic procrastination of elementary students in Pakdasht County. In other words, testing this hypothesis revealed that as teachers' social skills improve, the level of academic procrastination among their students decreases.

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Table 4-12: Pearson Correlation Test Results for Sub-Hypothesis 5

		Academic procrastination of students	Teachers' Social Skills
Academic procrastination of students	Pearson's statistic	1	-.177
	Significance statistic		.116
	Sample size	80	80
Teachers' Social Skills	Pearson's statistic	-.177	1
	Significance statistic	.116	
	Sample size	80	80

Sub-hypothesis 6: There is a relationship between teachers' resource management skills and academic procrastination of elementary students in Pakdasht County.

To examine this hypothesis, the Pearson correlation test was used. The results, presented in Table 4-13, indicate that the correlation coefficient between teachers' resource management skills and academic procrastination of elementary students in Pakdasht County is -0.631, with a significance level close to 0.000. This suggests that there is an inverse relationship between teachers' resource management skills and academic procrastination of elementary students in Pakdasht County. In other words, testing this hypothesis revealed that as teachers' resource management skills improve, the level of academic procrastination among their students decreases.

Table 4-13: Pearson Correlation Test Results for Sub-Hypothesis 6

		Academic procrastination of students	Teachers' Resource Management Skills
Academic procrastination of students	Pearson's statistic	1	-.631**
	Significance statistic		.000
	Sample size	80	80
Teachers' Resource Management Skills	Pearson's statistic	-.631**	1
	Significance statistic	.000	
	Sample size	80	80

Sub-hypothesis 7: There is a relationship between teachers' technical skills and academic procrastination of elementary students in Pakdasht County.

To examine this hypothesis, the Pearson correlation test was used. The results, presented in Table 4-14, indicate that the correlation coefficient between teachers' technical skills and academic procrastination of elementary students in Pakdasht County is -0.452, with a significance level close to 0.000. This suggests that there is an inverse relationship between teachers' technical skills and academic procrastination of elementary students in Pakdasht County. In other words, testing this hypothesis revealed that as teachers' technical skills improve, the level of academic procrastination among their students decreases.

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Table 4-14: Pearson Correlation Test Results for Sub-Hypothesis 7

		Academic procrastination of students	Teachers' Technical Skills
Academic procrastination of students	Pearson's statistic	1	-.452**
	Significance statistic		.000
	Sample size	80	80
Teachers' Technical Skills	Pearson's statistic	-.452**	1
	Significance statistic	.000	
	Sample size	80	80

Main Hypothesis: There is a relationship between teachers' job skills and academic procrastination of elementary students in Pakdasht County.

To examine this hypothesis, the Pearson correlation test was used. The results, presented in Table 4-7, indicate that there is an inverse relationship between teachers' job skills and academic procrastination of elementary students in Pakdasht County. These findings are consistent with both national and international studies conducted in this area. For example, the study by Momeni and Zohurparvaneh (2021) showed that the classroom's psycho-social atmosphere significantly contributes to reducing stress and academic procrastination. This aligns well with the current research, as a supportive psycho-social environment depends largely on teachers' process and social skills, which were confirmed in this study. Similarly, Zarei and Ajam (2020) emphasized that teachers' planning skills have a significant negative relationship with procrastination—an outcome that this research also confirmed, particularly in relation to resource and content management skills. Furthermore, the study by Ranjbar and Bayanfard (2019) demonstrated that teachers' personality traits and sense of responsibility play a key role in reducing procrastination and increasing students' motivation. This helps interpret the observed relationship between teachers' problem-solving and systems-related skills and reduced procrastination. Additionally, the findings of Monadi and Esmaeili (2016) identified teaching methods as one of the influential factors on students' procrastination, which is in line with the present study, as teaching methods are directly related to various skills, including teachers' technical skills.

In the domain of international studies, the research conducted by Steel et al. (2022) and Lee (2021), which emphasized the role of teaching methods and the classroom's psychosocial environment in reducing procrastination, aligns with the findings of the present study regarding teachers' social, technical, and process skills. These findings indicate that teachers can significantly impact students' academic procrastination by fostering a supportive environment and adopting appropriate teaching styles.

Moreover, the results of the study by Kudina et al. (2020), highlighting the importance of supportive teaching styles and their effect on satisfying students' psychological needs, further reinforce the present study's findings concerning the role of teachers' problem-solving and resource management skills in reducing procrastination.

First Sub-Hypothesis: There is a relationship between teachers' process-oriented skills and students' academic procrastination in primary schools of Pakdasht County.

To examine this hypothesis, the Pearson correlation test was used. As shown in Table 4-8, there is an inverse relationship between teachers' process skills and the academic procrastination of elementary students in Pakdasht County. The study results revealed that teachers' process skills—such as systematic planning, classroom organization, and time management—have a significant impact on reducing students' academic procrastination. Teachers who are capable of implementing these skills bring order and clarity to the classroom, clearly communicate assignments, and minimize ambiguity in tasks.

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Studies such as the one conducted by Zarei and Ajam (2020) have also demonstrated that teachers' planning skills are negatively associated with procrastination. Lee (2021) similarly emphasizes that creating a positive psychosocial classroom climate can reduce academic procrastination—an assertion that aligns with the findings of this research.

Second Sub-Hypothesis: There is a relationship between teachers' content-oriented skills and students' academic procrastination.

To test this hypothesis, Pearson's correlation test was used. According to Table 4-9, there is an inverse relationship between teachers' content-oriented skills and students' academic procrastination in primary schools of Pakdasht County. Content-oriented skills, such as mastery of the subject matter and the ability to convey concepts, help teachers engage students in learning and encourage them to actively participate in the educational process. The findings of the study indicate that these skills are inversely related to academic procrastination. A study by Kodina et al. (2020) also emphasized the importance of supportive teaching styles and fulfilling students' psychological needs. The results of the current study align with these findings, showing that teachers with content-oriented skills can enhance students' motivation and reduce procrastination.

Third Sub-Hypothesis: There is a relationship between teachers' system-related skills and students' academic procrastination.

To test this hypothesis, Pearson's correlation test was used. According to Table 4-10, there is an inverse relationship between teachers' system-related skills and students' academic procrastination in primary schools of Pakdasht County. System-related skills, including managing and overseeing class interactions and setting structural frameworks, have a significant impact on reducing students' procrastination. Teachers with these skills are able to create clear expectations and align the educational system with students' needs. Studies by Monadi and Esmaeili (2016) and Steele et al. (2022) have shown that teaching methods and a supportive environment play a crucial role in reducing academic procrastination. The results of this study confirm this point.

Fourth Sub-Hypothesis: There is a relationship between teachers' problem-solving skills and students' academic procrastination.

To test this hypothesis, Pearson's correlation test was used. According to Table 11-4, there is an inverse relationship between teachers' problem-solving skills and students' academic procrastination in primary schools of Pakdasht County. This study found that teachers' problem-solving skills have a significant effect on reducing procrastination. Teachers who are capable of solving classroom challenges and helping students overcome academic barriers can increase students' confidence and encourage them to complete assignments on time. Research by Ranjbar and Bayanfar (2019) showed that responsibility and problem-solving skills of teachers are positively related to reducing procrastination. Akbay and Gezer's (2020) research also emphasizes that time management and motivation skills can reduce procrastination behaviors.

Fifth Sub-Hypothesis: There is a relationship between teachers' social skills and students' academic procrastination.

To test this hypothesis, Pearson's correlation test was used. According to Table 12-4, there is an inverse relationship between teachers' social skills and students' academic procrastination in primary schools of Pakdasht County. Social skills, including the ability to establish positive relationships and encourage students to interact with each other, have a meaningful impact on reducing procrastination. The results show that teachers with stronger social relationships encourage students to be more responsible. The findings of this study are consistent with studies such as Momeni and Zohoor Parvaneh (2021) and Li (2021), which demonstrated that a positive psychological-social classroom environment reduces procrastination.

Sixth Sub-Hypothesis: There is a relationship between teachers' resource management skills and students' academic procrastination.

To test this hypothesis, Pearson's correlation test was used. According to Table 13-4, there is an inverse relationship between teachers' resource management skills and students' academic procrastination in primary schools of Pakdasht

County. The findings indicated that teachers who can manage resources such as time, educational tools, and energy can assist students in completing assignments and reduce procrastination behaviors. The research by Akbay and Gezer (2020) also points to the importance of teachers' time management in reducing procrastination and is consistent with the results of this study.

Seventh Sub-Hypothesis: There is a relationship between teachers' technical skills and students' academic procrastination.

To test this hypothesis, Pearson's correlation test was used. According to Table 4-14, there is an inverse relationship between teachers' technical skills and students' academic procrastination in primary schools of Pakdasht County. Technical skills, including the use of technology and modern educational tools, facilitate the learning process and, as a result, reduce academic procrastination. Teachers who possess these skills create a more engaging and interactive educational environment. The findings of this study are consistent with those of Kodina et al. (2020), which emphasize the importance of supportive teaching styles, and with the research of Monadi and Esmaeili (2016), which highlights the importance of teachers' teaching methods.

Limitations of the Study

1. The main limitation of any study can be the ability to generalize its results to other statistical populations. This study was conducted within the teacher population of Pakdasht County, and therefore, generalizing its findings to all teachers and students across the country seems challenging.
2. A limitation in distributing and collecting the questionnaires includes the reluctance of some sample members to respond, lack of accuracy in answering questions, and potential biases that some sample members may have when answering certain questions.

Suggestions
• Conduct training courses to teach process-oriented skills to the teachers in the study group.
• Content-oriented skills should be outlined in extracurricular sessions for teachers to reduce procrastination among students.
• Systems and related skills should be taught to teachers through specialists in this field.
• Use psychologists and educational counselors to explain problem-solving skills and their role in reducing student procrastination.
• Social skills and their dimensions should be distributed among teachers in the form of educational pamphlets to reduce academic procrastination among their students.
• In collaboration with the Technical and Vocational Training Organization, strengthen the technical skills of teachers to help reduce academic procrastination among students.

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New Approaches to Personalized Learning: Concepts, Methods, and Challenges

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ABSTRACT

Personalized learning provides learning experiences tailored to individual needs and abilities. This review article examines three main approaches to this type of learning: adaptive learning systems, educational recommender systems, and gamification. These methods enhance learners' academic performance and motivation by offering personalized content, instant feedback, and interactive environments. Adaptive systems optimize learning paths, recommender systems suggest appropriate resources, and gamification makes learning more engaging. However, there are challenges such as lack of financial resources, the need for teacher training, and privacy issues. To overcome these barriers, investment in technology, teacher training, and the development of security policies are essential. Future research should focus on developing cost-effective technologies and integrating these approaches with traditional education. Personalized learning has great potential to transform education but requires addressing its challenges.

Keywords: Personalized Learning, Adaptive Learning, Educational Recommender Systems, Gamification

INTRODUCTION

Learning is one of the most fundamental human needs for personal and social growth and development. From the beginning of life, it has served as the primary tool for understanding the world, acquiring skills, and transferring knowledge (Davarpanah, 2019). The importance of learning in advancing personal, social, and professional life is so critical that developed societies constantly seek to enhance educational and learning methods (Sadeghi Tabar & Shariatmadari, 2020). In a world that is rapidly changing and advancing, the ability to engage in continuous learning is not only an advantage but a necessity (Ahmad & Mohammadi, 2020). With the daily progress of science and technology, we are witnessing fundamental changes across various fields of knowledge. A massive volume of information and new knowledge is produced daily, which highlights the growing need for efficient and flexible learning methods. In this context, traditional educational approaches—often designed uniformly and without considering individual differences—can no longer meet the diverse needs of learners (Alboghbish et al., 2019).

To keep pace with these developments, it is essential to pay attention to innovative learning approaches. Personalized learning is one such approach that adapts the educational process to learners' needs, interests, and abilities, providing a unique and effective experience. This approach not only increases learner motivation and engagement but also significantly enhances the efficiency and effectiveness of learning (Amzil et al., 2023). In recent years, with the emergence of advanced technologies such as artificial intelligence, machine learning, and big data analytics, new trends in personalized learning have emerged. These technologies enable a more precise analysis of learners' behaviors and the delivery of educational content tailored to their individual characteristics (Vandewaetere & Clarebout,2014). However, despite significant advancements, there are numerous challenges in the implementation and utilization of these approaches.

This review article aims to examine the concepts, methods, and challenges related to innovative approaches in personalized learning. To this end, it first explores the importance of personalized learning and its role in transforming educational systems. Subsequently, it analyzes technology-based modern approaches. Finally, it discusses the challenges facing this field and possible solutions to overcome them.

Research Background

The Importance of Personalized Learning

Personalized learning is one of the modern paradigms in education, in which the content, methods, and pace of learning are tailored to the individual needs, abilities, and interests of each student. Unlike traditional methods that usually follow a "one-size-fits-all" model (Pan,2018), this approach emphasizes differentiated instruction aligned with students' individual characteristics. Studies have shown that employing innovative educational methods suited to learners' personal traits facilitates skill mastery and the development of knowledge structures (Abedi et al., 2020).
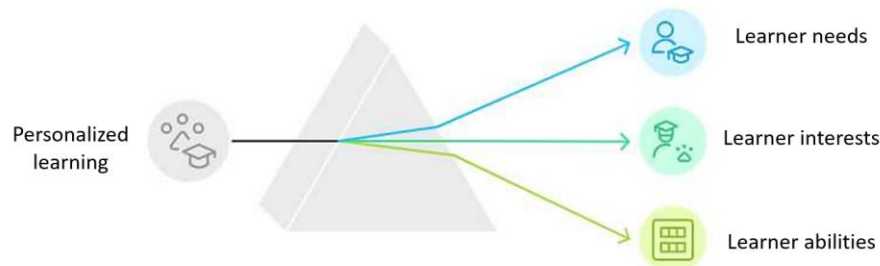

Figure 1 – Exploring the Dimensions of Personalized Learning

In this type of learning, the student becomes the point of the learning process, and the teacher acts as a facilitator. Based on their strengths and weaknesses, students receive instructional content and learning activities that match their specific needs. This means that student data is collected and analyzed to identify each individual's learning needs. Based on these analyses, the educational content is custom-designed to create a personalized learning experience for each learner (Naderi et al., 2021).
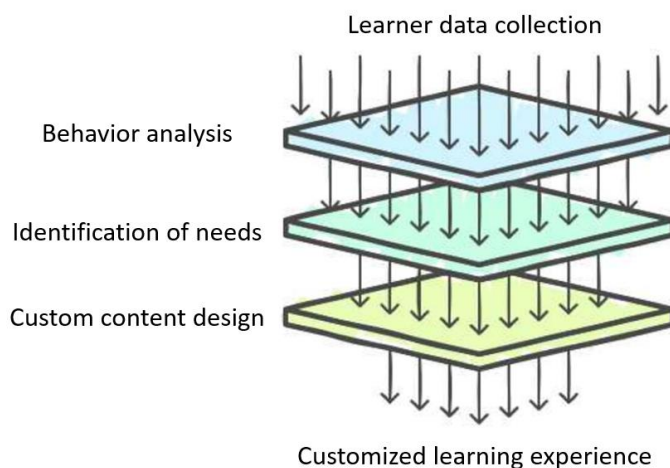

Figure 2 – Transforming Data into Personalized Learning

Technological tools such as Learning Management Systems (LMS), adaptive learning software, and artificial intelligence technologies play a key role in implementing personalized learning. These technologies enable more precise analysis of learners' behaviors and the delivery of educational content aligned with their individual characteristics (Yılmaz, 2024). The table below is provided to present the research background regarding innovative approaches to personalized learning.

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Author's Name	Title of the Research	Brief Description of the Research	Advantages of the Implemented Method	Challenges of Personalized Learning
Mansur et al. (2019)	Personalized learning model based on deep learning algorithm for student behaviour analytic	This study presents a personalized learning model based on deep learning algorithms to identify appropriate learning methods for students. Personalized learning factors such as adaptability, individualization, differentiation, and competency-based learning were considered. The proposed model outperformed other classification methods with a success rate of 72%, and it can help improve student performance and reduce failure rates.	Using deep learning to enhance the accuracy and efficiency of the model.	**- Lack of attention to students' abilities and the difficulty level of suggested materials.** **-Issue of insufficient assessment data.** **-Challenges in aligning the model with individual student needs.** **-Need for continuous improvement of learning pathways.**
Taylor et al.(2021)	Personalized and adaptive learning.	This article explores the concept of personalized and adaptive learning and examines its implementation in STEM fields. Using a fictional scenario, the paper presents definitions, benefits, impacts, opportunities, challenges, and future research directions. The findings indicate that adaptive learning can improve student performance by providing individualized learning pathways.	-Providing individualized learning pathways - Improving student performance - Reducing learning time - Delivering immediate feedback	**-Lack of clear standards for adaptive technologies** **- Resistance from instructors to adopt these methods** **- Need for financial and time resources to develop content** **- Challenges related to creating adaptive content**
Sari et al.(2024)	Improving Educational Outcomes Through Adaptive Learning Systems using AI.	This study examines the impact of AI-based adaptive learning systems on educational outcomes. Using a mixed-methods approach (quantitative and qualitative), a significant improvement in student performance was observed, with average scores increasing from 68.4 to 82.7 after the use of adaptive systems.	-Providing personalized learning paths - Increasing student engagement - Improving course completion rates	**-Technical readiness of educational institutions** **-Need for trainer education** **- Insufficient technical infrastructure** **-Ethical issues such as bias and data privacy Resistance of trainers to change**

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Emami and Jahaniyan (2022)	Examining and Analyzing Adaptive Learning in E-Learning for the Primary Education Level	This research examines the impact of adaptive learning in e-learning on primary school students. Adaptive learning is defined as a flexible and personalized teaching method that uses intelligent technologies to adjust educational content according to each student's needs and knowledge level. The results indicate that adaptive learning, considering the individual differences of students, enhances the effectiveness and efficiency of learning activities. It increases learning effectiveness, personalizes education, and improves interaction between teachers and students.	-Increased learning effectiveness - Personalization of education - Improved interaction between teachers and students	**-Many schools and teachers do not have access to the necessary technologies for implementing adaptive learning.** **- Teachers need specialized training to effectively use adaptive learning systems.** **-There are concerns about data privacy and potential biases in AI algorithms.**
Gupta et al. (2024)	- Adaptive Learning Systems: Harnessing AI to Personalize Educational Outcomes	This study examines Artificial Intelligence (AI)-based Adaptive Learning Systems (ALS), which use data analysis and machine learning algorithms to dynamically adjust content and assessments to each learner's needs in real time. These systems provide timely feedback and adapt learning paths, creating a more personalized and effective learning experience. The results show that using such systems leads to a 15% improvement in student scores and increased engagement in educational activities. Additionally, these systems offer instant feedback and make the learning environment more interactive and engaging..	-Personalization of content and assessments based on individual needs - Real-time feedback delivery - Increased student engagement and motivation - Identification of learning gaps and adaptation of instructional strategies	**-Systems may favor certain learning styles or demographic groups** **-Collection and analysis of student data raise ethical and security concerns regarding data privacy** **-Some teachers may resist shifting from traditional methods to new systems** **-Both teachers and students require training and technical support to use these systems effectively** **-Technical challenges such as software issues and the need for continuous technical support**
Saberi & Gholamali (2010)	Personalization of E-Learning Environment Using a Fuzzy Recommender Based on the	This study focused on the design and implementation of a fuzzy recommender system to personalize e-learning environments based on the integration of	-Increased learner satisfaction and academic success -Reduced learning time	**-The need for accurate identification of learner characteristics**

	Integration of Learning Style and Cognitive Style	learning style and cognitive style. Using fuzzy logic theory and learning style questionnaires, the proposed system extracted learners' characteristics and provided personalized recommendations. The results showed that combining learning and cognitive styles in personalized recommendations led to increased learner satisfaction and academic success. Academic satisfaction reached 85.7%, and academic success rose to 87%.	- Decreased unnecessary referrals - Improved performance of e-learning systems	**- Complexity in designing and implementing fuzzy systems - Requirement for continuous monitoring and updating of the learner model - Challenge in aligning content with diverse learning styles.**
Rezaeifard et al. (2023)	A Model for Recommender Systems of Information Resources in Iranian Library Software.	This study investigates the status of Iranian library software in terms of recommending resources to users and proposes a model for recommender systems within these platforms. Data were collected through interviews with library software managers and experts and analyzed using MAXQDA software. The findings revealed that while Iranian library software utilizes modern technologies, the familiarity of managers and experts with recommender systems is at a moderate level. The proposed model is a hybrid approach combining content-based filtering and collaborative filtering..	Using hybrid methods (content-based and collaborative filtering) to provide personalized recommendations to users.	**- Insufficient familiarity of managers and specialists with recommender systems (33% unfamiliarity) -Technical and non-technical challenges in implementing recommender systems - Lack of personalized user data**
Pengyu et al. (2024)	Collaborative Filtering Recommender System for Online Learning Resources with Integrated Dynamic Time Weighting and Trust Value Calculation.	This study proposes an improved Collaborative Filtering (CF) algorithm for recommending Online Learning Resources (OLR), which combines dynamic time-weighting and a trust selection strategy. The algorithm analyzes learners' interactions and ratings to calculate similarity and trust among them, and applies dynamic time-weighting to CF algorithms based on	- Improved accuracy in rating predictions - Integration of dynamic time-weighting and trust calculation - Addressing the issues of sparse data and cold start	**- Lack of attention to temporal changes in learners' preferences -Ambiguity in resource classification due to multiple labels - Incomplete utilization of relationships among learner feature information**

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		both OLR and learners. Experimental results show that the proposed algorithm significantly outperforms traditional and other enhanced algorithms in terms of performance metrics.		- Lack of quality control over online learning resources
Moradi & Majidi (2023).	The Role of Gamification in Teaching Persian Grammar (Topic: Descriptive and Ezafeh Compounds).	This study examines the impact of using educational games in teaching Persian grammar, specifically the topic of descriptive and ezafeh compounds, among sixth-grade students. Two classes were selected as samples: one with traditional teaching methods and the other with game-based teaching. The results showed that students taught with the game-based method achieved an average score of 89.1%, while the traditional class scored 56.6%. Additionally, both parents and students expressed higher satisfaction with the game-based approach.	- Increased motivation and interest of students in learning. - Creating a joyful and lively atmosphere in the classroom. - Deeper and more lasting understanding of concepts.	-The need for careful and purposeful game design. -Time-consuming preparation and implementation of games. -The need for active teacher involvement in the games. - The possibility that the games may not align with the learning level of all students.
Mohammadi et al. (2022).	Gamification with Leaderboard: The Impact of Competition- and Collaboration-Based Educational Tools on Learning and Motivation in Mathematics	This study examines the impact of educational tools Kahoot and Mentimeter, based on competition and collaboration elements, on learning and motivation in mathematics. The results showed that the use of the collaboration-based Mentimeter tool had a more significant impact on student learning and motivation than the competition-based Kahoot tool.‌ارد.	- Increased student motivation and engagement. - Creating an enjoyable and entertaining learning environment. - Improved learning and intrinsic motivation through collaboration and participation.	- The need for access to the internet and technological tools. - Challenges in time and resource management for implementing game-based methods. - The need for precise design tailored to the students' level.

Based on the aforementioned studies, three main approaches can be identified as innovative methods in personalized learning: adaptive learning systems, educational recommender systems, and gamification.

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I. AI-Based Adaptive Learning Systems

Adaptive learning is one of the most advanced approaches to personalized learning, utilizing cutting-edge technologies such as artificial intelligence and data analytics (Tahmasbi et al., 2018). This method continuously monitors learners' behavior and performance to optimize learning paths for each individual. In this approach, educational systems dynamically adjust instructional content based on each student's needs, strengths and weaknesses, and learning pace. For instance, if a learner encounters difficulties with a particular topic, the system automatically provides activities and materials designed to address that issue (Gupta, 2024).

A review of the existing research indicates that adaptive learning systems, by offering personalized learning experiences, have significantly contributed to improving academic performance and increasing student engagement. By tailoring both content and learning pathways to each student's needs and learning style, this approach creates a more flexible and effective learning environment (Ibid., Gupta). Notable benefits of these systems include enhanced student efficiency and participation, improved academic outcomes, and higher course completion rates (Vali Tabar & Moeinikia, 2016).

One of the key advantages of adaptive learning is the provision of immediate and accurate feedback, helping students recognize and correct their mistakes. This also allows students to learn concepts more independently and efficiently. However, challenges such as the need for adequate infrastructure, teacher training and readiness, and privacy concerns still exist and must be addressed for the effective implementation of these systems in educational environments. These challenges can impact the widespread adoption of this approach (Emami & Jahanian, 2022).

Therefore, greater focus on research and development in this area—particularly in resolving infrastructural issues and enhancing instructional strategies—is essential to fully realize the potential of adaptive learning. By overcoming these barriers, adaptive learning can serve as a key solution for creating more effective and personalized learning environments across all levels of education. This approach not only enhances learning outcomes but also empowers students to participate in the learning process with greater confidence and to acquire essential skills for life and work in the 21st century.

II. Educational Recommender Systems

Educational recommender systems are another vital tool in personalized learning. By analyzing individual data, they suggest content, courses, and learning activities tailored to the learners' needs and interests. These systems, leveraging technologies such as machine learning, create more targeted and effective learning environments. Additionally, using data analysis algorithms and big data analytics, they identify learning patterns and provide personalized feedback (Oefenlauer & Drachsler, 2020).

Extensive access to data has a direct impact on personalized learning. The more information available about students' performance and needs, the more accurate the learning predictions become, resulting in improved educational outcomes. However, a lack of data and challenges related to data collection can reduce the quality of instruction and make the implementation of personalized learning more difficult (Bousbia & Belamri, 2014).
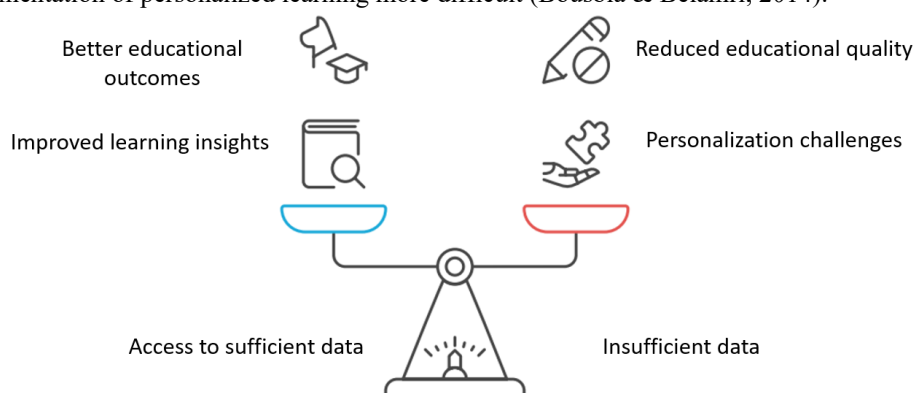

Figure 3 – The Impact of Data Accessibility on Personalized Learning

One of the key advantages of educational recommender systems is saving learners' time and energy. Instead of spending a long time searching for appropriate resources, the recommender system suggests content that best matches the learner's needs (Rezaeifard et al., 2023). For example, by using specific algorithms and methods, recommender systems identify the most suitable items—such as data, information, or materials—and suggest the ones that most closely align with the user's preferences. In an online course, if a student struggles with a particular

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topic, the system analyzes their progress data and recommends relevant resources such as videos, articles, or additional exercises (Heydari & Kargar, 2012).

III.   Gamification and Personalized Learning

Gamification is one of the creative methods in personalized learning that enhances the learning process by incorporating game elements and mechanics, making it more engaging and interactive (Moradi & Majidi, 2023). This approach involves using features such as scoring, leaderboards, rewards, and challenges to increase learners' motivation and engagement. One of the main goals of gamification is to transform learning into an enjoyable and exciting experience. Through game-like challenges, students not only learn new concepts but also develop skills such as problem-solving, teamwork, and creative thinking (Mohammadi et al., 2022).

This approach is particularly beneficial in educational environments, especially for younger students who require more motivation and interaction. Additionally, gamification can improve students' learning experiences, enhance their problem-solving abilities, strengthen logical thinking, increase focus and patience, reduce fatigue, improve collaboration and communication skills, and ultimately boost their overall performance in the educational process. Moreover, it contributes to improving the quality and efficiency of education (Rezapour et al., 2023).

One of the challenges of this method is the proper design of games and ensuring their alignment with educational objectives. It is also important to avoid fostering unhealthy competition or overemphasizing external rewards. Nonetheless, as a modern approach in personalized learning, gamification serves as an effective tool for boosting students' motivation and participation, contributing to the creation of dynamic and engaging learning environments (Mohammadi et al., 2022).

Challenges of Personalized Learning

Personalized learning, as an innovative approach, holds significant potential to transform educational systems and enhance learning quality. AI-based adaptive learning systems, educational recommender systems, and gamification are among the key strategies that can contribute to providing personalized learning experiences. However, the successful implementation of these approaches faces multiple challenges (Gupta, 2024). This article examines three main challenges: limitations in resources and technology, the need for teacher training, and issues related to privacy protection.

One of the main obstacles to implementing personalized learning is the lack of financial resources and appropriate technologies (Sari et al., 2024). Many schools and educational institutions, particularly in underdeveloped regions, lack access to advanced equipment such as computers, tablets, and personalized educational software. Furthermore, inefficient internet infrastructure can be a serious barrier to implementing digital and personalized learning. The high costs of acquiring and maintaining these technologies also place an additional burden on educational budgets (Zinivandnejad, 2020).
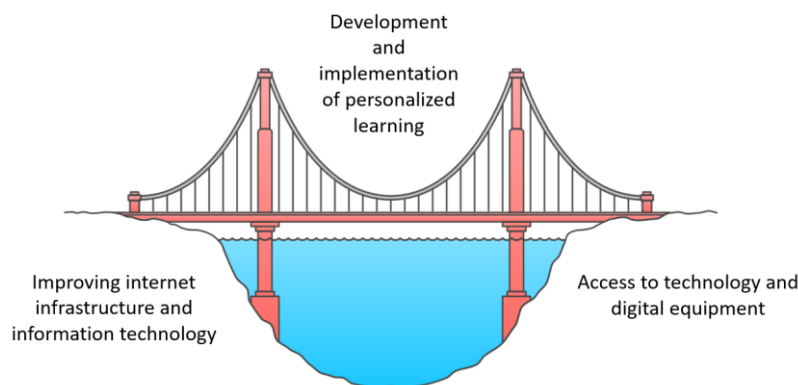

Figure 4 – Implementing personalized learning requires technological infrastructure.

As a solution, the use of low-cost digital tools such as tablets and open-source software can help reduce expenses. In addition, overcoming this challenge requires investment in improving internet and IT infrastructure in schools, especially in deprived areas (Rezaei et al., 2022).

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The second barrier to implementing personalized learning is the need for teachers who can effectively utilize digital tools and modern teaching methods. Many teachers lack the necessary knowledge and skills in this area and require specialized training. Designing training programs to familiarize teachers with the principles of personalized learning is essential for the success of this approach (Zinivandnejad, 2020). Organizing training courses for teachers on the use of new technologies and personalized teaching strategies can enhance their skills. These workshops help teachers become familiar with innovative educational tools. Moreover, forming professional communities among teachers for exchanging experiences and best practices can improve teaching quality. These networks provide a platform for knowledge and experience sharing. It is important to note that technology should be used as a tool to complement and enhance traditional teaching methods, not replace them. Combining technology with classical teaching methods can enrich the learning experience for students (Zinivandnejad, 2020).

The use of digital technologies in personalized learning relies on collecting and analyzing students' personal data. This raises concerns about privacy and data security. Many parents and policymakers worry about the potential misuse of children's sensitive information. In addition, privacy-related laws and regulations in many countries are either outdated or not fully developed (Raeesi & Ghasemzadeh, 2020). These issues may weaken users' trust in personalized educational systems. Therefore, developing and enforcing clear policies for the collection, storage, and use of student data is essential to safeguard their privacy. These policies must comply with international standards. Moreover, raising awareness about the importance of privacy and methods for protecting personal information can help reduce the risks associated with privacy violations. Such training should be included as part of the school curriculum. By implementing these strategies, the challenges to adopting personalized learning can be reduced, leading to improved educational quality (Ghanad & Aligholi, 2020).

Despite its numerous advantages, personalized learning faces major challenges related to resources, technology, teacher training, and privacy protection. To overcome these barriers, long-term investments in technology, education, and the development of appropriate legal and ethical infrastructures are necessary. Only by addressing these challenges can the full potential of this innovative method be realized and a better learning experience be provided for students.

Conclusion

This review article examined modern approaches to personalized learning, including adaptive systems, educational recommender systems, and gamification, aiming to analyze their concepts, benefits, and challenges. The findings indicate that personalized learning, through the use of advanced technologies such as artificial intelligence and data analytics, can tailor the learning experience to the individual needs, abilities, and interests of learners. This personalization not only enhances the quality of learning but also increases learners' motivation and engagement (Yilmaz, 2024). Studies such as Abedi et al. (2020) and Taylor et al. (2021) have yielded similar results, emphasizing the positive impact of personalized learning on educational outcomes and student interaction.

The findings show that adaptive systems can create a more effective learning experience by providing personalized content and feedback based on learners' performance and needs (Emami & Jahanian, 2022). Likewise, recommender systems suggest content and activities aligned with the learners' educational needs by analyzing their data (Rezaeifard et al., 2023), and gamification, through motivational elements such as scoring and game-like challenges, makes the learning process more engaging and interactive (Mohammadi et al., 2022).

However, limited financial resources, lack of technological infrastructure in some areas, and teachers' resistance to shifting from traditional methods to innovative approaches are among the major barriers to implementing these methods. Moreover, concerns about protecting learners' data privacy may affect users' trust in these systems.

To overcome these challenges, it is essential to invest in improving technological infrastructure, design training programs for teachers, and establish robust privacy protection regulations. Future research should focus on developing cost-effective technologies, designing smarter games and recommender systems, and examining the long-term effects of these methods on learning. It is recommended that future studies explore the impact of personalized learning across different age groups and educational environments, design affordable solutions, develop ethical and legal frameworks, and integrate this approach with traditional education.

Ultimately, personalized learning, as an innovative approach, can not only enhance educational quality but also help students engage in the learning process with greater confidence and acquire the essential skills needed for life and work in the 21st century. By addressing existing challenges, this approach can serve as a key strategy in transforming educational systems and creating dynamic and effective learning environments.

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Enhancing Institutional Transparency to Curb Administrative Corruption: Islamic Perspectives and Policy Mechanisms

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Abstract

Combating corruption and achieving administrative justice are fundamental concerns of contemporary political systems and societies, necessitating the development of epistemological foundations and executive structures aligned with Islamic values and other credible doctrines. Despite the multifaceted nature of corruption, identifying its key bottlenecks—such as the concentration of authority in managerial positions, extensive human intervention, lack of effective use of information technology, administrative stagnation due to gerontocracy, and limited elite circulation—can assist oversight institutions in preventing and effectively addressing this phenomenon. Employing a descriptive-analytical approach, this study examines the necessary infrastructures and mechanisms to enhance administrative integrity. It proposes strategies including the establishment of a centralized transparency institution for organizations and administrations (SHAMSA), the creation of electronic administrative service offices to facilitate public reporting, the development of organizational integrity assessment indicators, the formation of administrative inspectors for overt and covert oversight, and the maximal utilization of information technology. These measures, grounded in the principles of transparency, meritocracy, youth empowerment, and universal oversight, not only contribute to reducing corruption bottlenecks but also foster public trust and citizen satisfaction, thereby paving the way for administrative justice, sustainable development, and enhanced legitimacy of governance systems.

Keywords: Institutional Transparency, Administrative Corruption, Anti-Corruption, Islamic Approach, Universal Oversight, Youth Empowerment, Administrative Stagnation

1. Introduction

Corruption, as a multifaceted phenomenon that undermines collective interests, is considered a fundamental threat to the efficiency of political and social systems from the perspective of governance and public law theories. This phenomenon, rooted in the violation of ethical principles and the abuse of public authority, not only hinders the achievement of sustainable development goals but also severely erodes public trust in governmental institutions. The term "corruption," derived from the Arabic root "Fasada"[3] (meaning deviation from proper function and violation of legitimate norms), is defined in English literature as "Corruption," referring to the transgression of ethical and legal principles. More precisely, corruption encompasses any act or phenomenon that diverts an organized system from its legitimate objectives and optimal functions[1]. In this regard, the World Bank and Transparency International define administrative corruption as the abuse of public power for private gain, influenced by factors such as personal interests, familial ties, or illicit influences[2].

In response to this challenge, transparency, as a cornerstone of good governance, plays a pivotal role in preventing and combating corruption. Transparency, within the framework of institutional theories, is defined as public access to information regarding governmental decision-making, power distribution mechanisms, and resource allocation. It requires the disclosure of the basis for decisions and public policies (except in cases of legally confidential matters or those related to national security). This process enhances accountability and legitimacy of governance systems by enabling public evaluation and oversight of institutional performance. Public assessments, shaped through active citizen participation in evaluating policies and decisions, not only influence the formulation of executive strategies but must also manifest objectively and tangibly in citizens' lived experiences, beyond governmental propaganda.

The consequences of corruption, particularly in administrative systems, encompass a wide range of harms, including tax evasion, undermining meritocracy, concentration of wealth among specific groups, social deprivation, erosion of public trust, obstacles to economic and social development, and violation of the rule of law. Moreover, corruption perpetuates cycles of injustice and inequality, jeopardizing the realization of social justice. In Iran's legal

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[3] [In Arabic]

system, which is based on a pre-established legislative framework, a comprehensive set of laws and regulations has been enacted to prevent and combat corruption. These include the Law on Enhancing Administrative System Integrity and Combating Corruption, the Law on Intensifying Penalties for Perpetrators of Bribery, Embezzlement, and Fraud, the Islamic Penal Code, the Law on Punishing Disruptors of the Country's Economic System, the Law on Punishing Collusion in Government Transactions, the Law Prohibiting Holding More Than One Government Position, the Law Prohibiting the Receipt of Commissions in Foreign Transactions, the Anti-Money Laundering Law, and the Citizens' Rights Charter[3]. Notably, the principle of transparency, as a fundamental tenet in Article 69 of the Citizens' Rights Charter, emphasizes the necessity of public access to information. However, the full realization of this legislative framework requires resolute commitment from executive institutions to effectively implement these laws at the societal level. The absence of such commitment could render the wisdom of the legislature in designing this legal framework ineffective.

To effectively combat administrative corruption, it may be necessary to redesign institutional structures, reform executive policies, or develop new strategies. In some cases, establishing new institutions with distinct functions from existing structures, and in others, revising laws or strengthening executive mechanisms, appears essential. The fundamental question of this study is: what are the primary bottlenecks in the emergence and proliferation of corruption within the administrative system, and how should executive mechanisms and operational criteria be designed to maximize their impact in fostering integrity in administrative environments, which serve as a critical foundation for advancing national affairs? Adopting a descriptive-analytical approach, this study examines the focal points of corruption, analyzes the challenges contributing to its spread, and evaluates strategies to combat it in each section. Accordingly, the present article is organized around three main themes: "Transparency," "Administrative Stagnation," and "The Discourse of Anti-Corruption.".

2. Oversight of Transparency: An Institutional Framework for Enhancing Administrative Integrity

Transparency, as a cornerstone of good governance and a pivotal tool in preventing and combating administrative corruption, plays an unparalleled role in enhancing the efficiency and legitimacy of administrative systems. Defined within institutional theories as public access to information regarding governmental decision-making and resource allocation mechanisms, transparency requires systematic and structured oversight of public institutions' performance. However, achieving transparency in administrative systems, particularly within the framework of organizational hierarchy, necessitates delegating oversight to competent institutions with legal authority. In Iran's legal system, this responsibility primarily rests with senior government officials, as hierarchical overseers, who evaluate the performance of their subordinates through direct or indirect inspections, whether announced or unannounced.

Despite the significance of transparency oversight, the absence of a structured and legally grounded inspection system in many administrative systems, including Iran's, has created significant challenges in achieving this goal. Fragmented oversight efforts reliant on the initiatives of committed individual managers, while valuable, lack the continuity and comprehensiveness needed to ensure systematic administrative integrity. From the perspective of religious frameworks, oversight is emphasized as both an ethical and practical principle in Quranic texts. These texts delineate oversight in two distinct forms: first, oversight of human performance, as referenced in verses such as Surah Al-Alaq, verse 14, and Surah Yasin, verse 65; and second, covert evaluation and testing, as indicated in Surah Al-Ankabut, verse 2[1]. This duality provides a conceptual model for designing oversight mechanisms: overt oversight, conducted openly with prior notice, and covert oversight, carried out without prior knowledge to assess performance integrity. This framework can serve as a foundation for developing operational strategies in the realm of transparency oversight.

In the context of overt oversight, senior government officials, such as heads of organizations or their deputies, can conduct periodic or ad hoc inspections of subordinate entities. However, in cases where time or structural constraints prevent these officials from participating, it is proposed to define a new role termed "administrative inspectors." These inspectors, operating under the supervision of entities like the General Inspection Organization of Iran, can be selected from the country's talented workforce and, after undergoing specialized training, undertake both overt and covert inspections. This mechanism aligns with Article 8(a) of the Law on Enhancing Administrative System Integrity and Combating Corruption, which outlines the duties of the Vice Presidency for Strategic Planning and Supervision and the Vice Presidency for Management Development and Human Capital in formulating transparency policies, strengthening information systems, recording the performance of executive bodies, providing public information, and meeting the information needs of oversight institutions[2]. Far from conflicting with these provisions, this mechanism complements them.

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Covert oversight, exclusively assigned to administrative inspectors, is designed to assess institutional integrity without prior notice. In this approach, inspectors may operate in the guise of clients, contract employees, or even permanent staff to investigate and document instances of corruption and violations. This form of oversight, which requires advanced training and occasionally the expertise of intelligence agencies, may include "integrity testing" by presenting corruption-inducing proposals to evaluate employee responses. To complicate the identification of inspectors' identities, specialized training in concealment techniques and oversight methods is essential. Simultaneously, publicizing the possibility of such inspections among employees can serve as a deterrent mechanism, heightening awareness and adherence to transparency principles.

Given that managers and heads of organizations, due to their central roles and extensive authority, are more exposed to corruption risks than other employees, oversight of this group must be prioritized with greater intensity. This is significant not only because of managers' key roles in decision-making and finalizing client-related processes but also because, as direct overseers of employees, they are likely to be aware of their subordinates' violations. Therefore, selecting competent and ethical managers, coupled with continuous and meticulous oversight of their performance, is a critical strategy for preventing corruption. Such oversight can be implemented through mechanisms akin to those used for intelligence operatives, such as anonymous workplace presence, to prevent large-scale corruption.

Ultimately, developing a comprehensive and multi-layered oversight system that integrates overt and covert mechanisms can serve as an effective tool for enhancing transparency and reducing administrative corruption. This system, grounded in the principles of good governance and leveraging religious and legal frameworks, not only ensures administrative integrity but also strengthens public trust and contributes to achieving sustainable development goals.

3. Oversight of Managers and Institutional Transparency: An Approach to Curbing Administrative Corruption Bottlenecks

One of the primary bottlenecks of corruption in administrative systems is the position of managers as final decision-makers in organizational processes. The concentration of authority in the hands of a single individual, as opposed to conciliar or consultative structures, creates opportunities for self-interested motives, as the absence of collective oversight and accountability mechanisms increases the potential for power abuse. In conciliar systems, social norms and collective ethical conscience, combined with the possibility of reporting violations, serve as barriers against corruption. This principle is rooted in ethical and religious frameworks, as exemplified by Imam Hassan Askari (AS), who stated: "Whoever does not feel shame before people will not fear God"[4]. This hadith underscores the role of social shame as a deterrent mechanism against ethical deviations. Accordingly, it is proposed that in designing administrative structures, the allocation of individual workspaces for managers and employees should be avoided to the extent possible. Instead, creating shared work environments with the presence of multiple employees or clients can reduce corruption risks by enhancing social oversight and leveraging collective ethical norms.

This oversight approach, grounded in strengthening social supervision, has historical and religious precedents. In the governance system of Amir al-Mu'minin Ali (AS), oversight of agents' performance through covert and overt inspections was a key strategy. For instance, in a letter to Malik ibn Ka'b, one of his governors, Imam Ali instructed him to appoint a trusted individual to act on his behalf and, accompanied by a group of companions, inspect the performance of agents in the region between the Tigris and Adhib rivers and report back[5]. Similarly, in Letter 53 of Nahj al-Balagha to Malik al-Ashtar, the qualities of overseers are emphasized: "Inspect their actions and appoint spies from among the truthful and loyal to monitor them." The Imam further highlights the critical impact of this oversight, stating: "Your covert attention to their affairs encourages them to uphold trust and treat the subjects with leniency." This framework not only underscores the importance of covert oversight but also highlights the selection of competent and committed overseers as a prerequisite for the success of this mechanism. Globally, specialized inspection institutions with extensive authority are tasked with overseeing public institutions and addressing public complaints[6]. For these oversight efforts to be effective, regular overt and covert inspections at short intervals (e.g., monthly inspections) are necessary to prevent corruption from taking root and spreading. This approach, by establishing a dynamic oversight system, can help curb corruption bottlenecks at managerial levels.

To complement this strategy, institutional transparency, particularly in governmental systems, requires resolute political will and access to organizational data and information. In centralized systems like Iran's administrative framework, the government, as the overarching authority, has the capacity to collect and disseminate information. However, merely publishing data, especially in complex areas such as budget allocation or project implementation, may lead to ambiguity or the spread of rumors due to the public's lack of expertise. For instance, the general public may not be able to assess the appropriateness or efficiency of a budget allocated to a project, which could result in

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misunderstandings or diminished public trust. To address this challenge, it is proposed that a unit called the "Information Analysis Unit" be established within the structure of the General Inspection Organization of Iran. This unit, by analyzing published data and providing qualitative, accessible reports for the public, can enhance transparency and facilitate public oversight. These reports, offering simplified yet accurate analyses, enable citizens to make informed judgments about matters related to public interests. Ultimately, integrating institutional, social, and informational oversight, alongside designing administrative structures based on principles of transparency and accountability, can serve as a comprehensive strategy for preventing corruption and enhancing administrative integrity. This approach, drawing on religious, historical, and comparative frameworks, not only mitigates corruption bottlenecks at managerial levels but also fosters public trust and supports the realization of good governance objectives.

4. Centralized Transparency: An Institutional Approach to Systematizing Public Access to Information

Transparency, as a cornerstone of good governance, requires systematic and integrated access to information from public institutions. Article 2 of the Draft Law on Transparency of the Three Branches, Executive Agencies, and Other Institutions envisages the transparency process through "systems related to each institution." This article, alongside Article 1, which lists more than twenty institutions subject to this law, provides a legal framework for information disclosure. However, the multiplicity of institutions and information dissemination systems, coupled with a lack of integration in the data publication process, creates significant challenges to achieving transparency objectives. The fundamental question is whether the general public is aware of these institutions and their respective systems. More importantly, are the published data organized in a manner that is accessible and comprehensible to the public? The lack of coherence in transparency mechanisms not only undermines the effectiveness of these efforts but also jeopardizes the primary goal of transparency—public oversight and enhanced accountability—by failing to inform citizens effectively.

From the perspective of institutional theories, any action lacking structural coherence and order is prone to failure, even if implemented on a large scale. To address this challenge and systematize the transparency process, it is proposed to establish an institution named the "Centralized Transparency Institution for Organizations and Administrations" under the supervision of the General Inspection Organization of Iran. This institution, by fostering coordination and integration in the performance of covered entities, can contribute to the sustainability and enhancement of transparency in the administrative system. Placing this institution under the oversight of the General Inspection Organization not only facilitates monitoring of its performance but also enables synergy with other oversight mechanisms, such as the proposed "Information Analysis Unit" (discussed in previous sections). The duties of this institution can be outlined as follows:

1. Data Analysis and Expertise: Specialized evaluation of information provided by organizations and administrations to ensure its accuracy and sufficiency.
2. Simplification of Information for the Public: Transforming raw and complex data into qualitative, comprehensible reports for citizens, enabling informed judgment about institutional performance.
3. Development of Standardized Indicators: Establishing uniform criteria and frameworks for categorizing and publishing information to ensure coherence in the transparency process.
4. Data Aggregation and Organization: Collecting information directly (by republishing data on the centralized transparency institution's system) or indirectly (by linking institutional systems through electronic connections).
5. Monitoring and Follow-Up on Performance: Continuous oversight of executive agencies' compliance with their commitments and follow-up on promises made by authorities to enhance accountability.
6. Collaboration with Oversight Institutions: Coordination with entities such as the Ministry of Intelligence to identify and address vulnerabilities to corruption.
7. Access to Information Databases: Leveraging legal access to data from governmental organizations and administrations for simplification, categorization, and publication.

Furthermore, establishing this institution can channel public demands for transparency to a single, clear authority, which is significantly simpler and more effective for citizens. To enhance public access and participation, it is proposed that this institution establish a network of "Electronic Administrative Service Offices" in various cities, similar to electronic judicial service offices. These offices, which could operate independently or as part of judicial service offices, would be responsible for receiving public reports on administrative corruption and referring them to competent authorities. Such a structure not only encourages citizen participation in combating corruption but also enhances public awareness of civic rights and duties while increasing the effectiveness of public oversight by reducing the fragmentation caused by multiple systems.

To facilitate reporting, a unified electronic system for registering administrative violations could be designed, which, unlike judicial complaints, would not require verification of the reporter's identity. This feature, by simplifying the reporting process, encourages public participation. Historically, the establishment of the "Bayt al-Qisas" during the governance of Imam Ali (AS) as the first formal mechanism for receiving public complaints against government agents and ordinary citizens serves as a pioneering example of direct public engagement with governance. This institution, which handled both administrative and judicial complaints, provides a model for designing modern oversight mechanisms. Although Article 173 of the Constitution designates the Administrative Court of Justice as the authority for addressing grievances against government officials, the establishment of electronic administrative service offices does not conflict with this court. First, these offices align with the court's objectives of safeguarding citizens' rights. Second, unlike the court, which focuses on handling formal complaints, the proposed offices concentrate solely on receiving corruption reports without requiring identity verification. This distinction highlights the complementary role of these offices in the country's oversight system.

Despite repeated emphases by the Supreme Leader on the necessity of forming an anti-corruption task force and his guidelines in this regard, the current systems of this task force still lack the necessary efficiency. This inefficiency has limited citizens' effective participation in reporting and combating administrative corruption. The establishment of the Centralized Transparency Institution and Electronic Administrative Service Offices, as part of a comprehensive oversight system, can address this gap and, by enhancing transparency and accountability, contribute to achieving the objectives of good governance and preventing corruption.

5. Information Technology and Enhancing Institutional Transparency: An Approach to Reducing Corruption in Administrative Systems

Information technology, particularly in the digital era and with the expansion of global internet networks, has become an unparalleled tool for strengthening transparency and preventing corruption in governance systems. Public access to the web, which enables the continuous and widespread dissemination and oversight of information, provides a unique platform for realizing the principles of institutional transparency. The publication of information related to governmental decisions, laws, executive actions, budget allocations, expenditures, and revenues—provided they are not classified as confidential under Article 8, Clause 11 of the Law on Handling Administrative Violations—not only fosters public participation but also facilitates fact-based decision-making and enhances citizens' trust in the performance of public institutions[7].

Despite the remarkable potential of information technology in advancing transparency, global data still indicate significant gaps in this area. According to the 2021 Transparency International report, Iran ranked 150th among 180 countries with a score of 25, placing it on par with countries such as Guatemala and Tajikistan. The report also notes a 30-rank decline in Iran's transparency index from 2011 to 2021[8]. A comparative analysis of leading countries in this index, such as Denmark, Finland, New Zealand, and Norway, versus countries with lower rankings, such as Sudan, Somalia, Venezuela, and Afghanistan, reveals a significant correlation between the use of information technology and transparency levels. Leading countries, by systematically integrating digital technologies into governance processes—including the publication of detailed government and electoral activities—have achieved high transparency standards[9]. In contrast, countries with limited use of these tools in their domestic policies face higher corruption risks and lower transparency rankings.

One of the key features of information technology in administrative systems is the reduction of reliance on human intervention in bureaucratic processes. This not only increases the speed and efficiency of processes but also significantly reduces the likelihood of errors and corruption by minimizing human involvement. Digital systems, due to their higher reliability and accuracy compared to human-dependent processes, enable the precise and lawful execution of administrative tasks. Within the framework of administrative modernization theories, this feature is recognized as a critical factor in enhancing the integrity of executive systems, as information technology promotes transparency in processes and reduces opportunities for abuse, thereby fostering public trust and achieving the objectives of good governance.

However, realizing the full potential of information technology in enhancing transparency requires the design and implementation of coherent policies and integrated digital infrastructures. The absence of such infrastructures, coupled with insufficient public awareness of how to access published information, can limit the effectiveness of this tool. To address this challenge, it is proposed that oversight institutions, such as the General Inspection Organization of Iran, develop centralized and user-friendly systems to facilitate public access to information. These systems, by providing simplified and comprehensible data, can enhance informed citizen participation and prevent transparency from becoming a superficial exercise. Ultimately, the integration of information technology into oversight and executive

frameworks, as a comprehensive strategy, not only helps reduce administrative corruption but also paves the way for sustainable development and the strengthening of the legitimacy of governance systems.

6. Administrative Stagnation and Youth Empowerment: An Institutional Approach to Preventing Corruption in Management Systems

Corruption, as a multifaceted phenomenon, often emerges in environments where material and personal interests overshadow incentives for reporting and accountability. In such contexts, relying solely on legal incentives for whistleblowing is ineffective, as the benefits derived from violations typically outweigh the rewards offered to informants. Moreover, the covert nature of corruption, which primarily occurs in limited interactions between involved parties, makes its detection challenging. Therefore, preventing corruption requires controlling the entry points of administrative systems, particularly through criteria for personnel selection and human resource management. One of the most critical criteria is attention to age and the age composition of the workforce in administrative environments.

From psychological and sociological perspectives, advancing age and entry into later stages of life are often associated with a decline in physical and cognitive capacities, which may lead to a desire to maintain or expand power and wealth. This inclination, sometimes manifested in efforts to secure social status or create a material legacy, may in some cases be pursued through illicit and corrupt means. In contrast, younger personnel, characterized by traits such as a desire for change, idealism, and boldness, are less prone to self-interested motives. This group, driven by creativity and enthusiasm for exploring innovative ideas, demonstrates a greater tendency to achieve organizational goals through lawful and innovative methods. However, experience, as a valuable asset in addressing challenges, should not be overlooked. A balanced combination of creative and operational young talent with the knowledge and experience of older individuals can serve as an effective strategy for preventing corruption and enhancing administrative integrity. In this regard, leveraging older individuals in advisory roles, such as knowledge management and experience transfer, not only provides a more suitable position for this group but also strengthens the efficiency of the management system.

Challenges arising from the management of administrative systems by older individuals, particularly those over 70, are linked to diminished cognitive capacities. Research indicates that after this age, the ability to absorb and process large volumes of new information and solve problems unconventionally significantly declines[10]. This phenomenon, referred to in academic literature as "gerontocracy," is characterized by traits such as conservatism, limited flexibility, resistance to elite circulation, reduced motivation among younger staff, and a threatening perception of the presence of young talent. These traits ultimately lead to administrative stagnation, which creates a fertile ground for corruption. Stagnation, whether in natural systems, individual beliefs, or management structures, fosters decline and undermines existing merits. Monopolistic tendencies, concentration of financial resources among specific groups, and lack of organizational dynamism are all manifestations of this stagnation, exacerbating corruption in administrative systems. To address this challenge, organizational dynamism, elite circulation, and knowledge transfer are proposed as key strategies for preventing corruption. Revitalizing management systems through targeted rotation of employees and managers in sensitive or corruption-prone positions can prevent the formation of corrupt networks. This approach, emphasized in Article 4 of the Law on Enhancing Administrative System Integrity and Combating Corruption as a duty of the Ministry of Intelligence to identify corruption-prone positions, also fosters creativity and innovative ideas through diverse work experiences. Such dynamism not only strengthens administrative integrity but also enhances organizational efficiency by increasing employee motivation and participation.

Within the framework of historical and religious experiences, the governance approach of Imam Ali (AS) provides a prominent model. By avoiding the appointment of relatives and close associates to positions of power and addressing violations by those close to him more decisively to eliminate perceptions of immunity due to proximity, Imam Ali demonstrated the role of informal relationships and familiarity in creating opportunities for corruption. A similar phenomenon can be observed in groups such as prisoners, who, after building trust and familiarity, collaborate to commit violations. To prevent such risks in administrative systems, the systematic rotation of employees and managers in corruption-prone positions is essential as a preventive mechanism. This strategy disrupts potential corrupt networks, reducing the likelihood of informal relationships and organized violations.

Ultimately, youth empowerment, as part of a comprehensive strategy to combat administrative stagnation, not only promotes dynamism in management systems but also enhances administrative integrity and efficiency by combining the creativity of younger personnel with the experience of older individuals. This approach, grounded in the principles of good governance and religious and historical frameworks, can mitigate corruption bottlenecks and contribute to achieving sustainable development goals.

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7. The Discourse of Anti-Corruption: An Approach to Strengthening Public Oversight and Enhancing Administrative Integrity

Oversight, as a cornerstone of corruption prevention, gains greater effectiveness in achieving justice-oriented and anti-corruption objectives as its scope and intensity increase. However, quantitative and qualitative limitations in governmental oversight capacities, such as a shortage of specialized personnel or structural complexities, raise fundamental questions: To what extent can governmental oversight of administrative institutions be expanded? And how can oversight institutions be strengthened to ensure their sustained efficiency? Addressing these questions hinges on leveraging the potential of public oversight and citizen participation in oversight processes. In this context, promoting universal oversight, which positions every citizen as an active monitor of administrative violations, can serve as a complementary strategy to address the limitations of governmental oversight. This approach, by transforming citizens into informed and responsible actors, not only broadens the scope of oversight over public institutions but also fosters public demand for combating corruption.

Universal oversight, beyond strengthening oversight processes, leads to the creation of a widespread social demand that compels governmental institutions to enhance accountability and effectively implement anti-corruption policies. This demand, rooted in a sense of civic duty and reciprocal expectations from the state, acts as a driving force to improve the performance of public institutions in alignment with justice-oriented and administrative integrity goals. A key strategy for realizing universal oversight and nurturing social monitors is the development of an anti-corruption discourse. Discourse-building, defined in political science as the production and reproduction of meanings and values in a specific domain through dialogue, writing, and social interactions, can sensitize public consciousness to corruption and the need to combat it, thereby awakening the collective conscience[11]. This process, by promoting ethical and religious values in academic circles, media, books, and research articles, creates a foundation for restoring the social stigma of corruption. Evidence of this impact can be seen in the well-known saying, "People follow the religion of their rulers," which highlights the role of governmental policies and actions in shaping social behavior and values[12].

In cases where material interests entice individuals to engage in corruption and disregard ethical and religious values, the erosion of the social stigma of corruption emerges as a significant cultural harm. In such contexts, discourse-building, by reconstructing the collective conscience and reinforcing ethical values, can serve as a deterrent mechanism. This process, by raising societal awareness of the consequences of corruption, not only strengthens resistance to corrupt inducements but also prevents the spread of this organizational harm by encouraging the reporting of violations[13]. Consequently, the anti-corruption discourse, as a soft tool, contributes to enhancing administrative integrity and achieving the objectives of good governance.

From the perspective of modern discourse theories, particularly Michel Foucault's views, discourse serves as a nexus of power and knowledge, playing a pivotal role in shaping social and political relationships. Foucault considers discourse not only a tool for producing truth and scientific legitimacy but also a means of exercising power indirectly and softly[14]. Within this framework, the anti-corruption discourse, as a dual-purpose tool, enables mutual influence between the public and the state. The state, through anti-corruption policies and the promotion of anti-corruption values, can guide social behavior, while citizens, through public demand and oversight, steer state power toward implementing transparent and accountable policies. This interaction creates a positive cycle that sustains universal oversight and reduces corruption.

Alongside discourse-building, sustained cultural initiatives can also contribute to preventing corruption in administrative environments. Organizing programs such as cultural competitions centered on anti-corruption themes, utilizing religious verses and narrations, academic books and articles, and related judicial cases, can raise public awareness and institutionalize anti-corruption values in society. These initiatives, by fostering a sense of social responsibility, encourage citizens to actively participate in oversight processes. Ultimately, combining discourse-building with cultural programs, as part of a comprehensive strategy, not only helps mitigate corruption bottlenecks in administrative systems but also, by strengthening collective conscience and public demand, paves the way for achieving sustainable development goals and enhancing the legitimacy of governance systems.

Summary and Conclusion: Formulating Comprehensive Strategies for Preventing and Combating Administrative Corruption

Corruption, as a persistent social and organizational harm, has long permeated both administrative and non-administrative systems across various societies, posing fundamental challenges for governments and nations. Every political and legal system, in accordance with its structures and values, has devised strategies to curb this phenomenon. In Iran's legal system, a comprehensive legislative framework, including laws such as the Law on Enhancing

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Administrative System Integrity and Combating Corruption, the Anti-Money Laundering Law, and the Citizens' Rights Charter, has achieved relatively successful outcomes in preventing and addressing administrative corruption. However, shortcomings in areas such as administrative procedural regulations or the lack of transparency in certain covert oversight policies continue to hinder the full realization of anti-corruption objectives. Disclosing these policies, alongside the legalization of oversight mechanisms, can contribute to eliminating this harm from the administrative system by reducing incentives for corruption and strengthening legal deterrence. This requires lawmakers to pay closer attention to the wisdom behind legislation and to design transparent and systematic oversight structures. Based on the discussions presented in this study, the relationship between corruption, corruption-prone points, and preventive factors can be articulated in a simplified conceptual model as follows:

$$\text{Corruption} = (\text{Transparency} + \text{Meritocracy} + \text{Youth Empowerment} + \text{Social Conscience and Shame}) - (\text{Power Monopoly} + \text{Secrecy})$$

This model emphasizes the role of preventive factors such as transparency, meritocracy, and social shame in reducing corruption, while identifying power monopolies and secrecy as primary drivers of this phenomenon. Although completely eliminating the root causes of corruption, such as monopolistic tendencies, may be challenging due to their complex nature—as noted in religious culture as an inherent characteristic of power[15]—Imam Ali (AS) states in this regard: "Whoever attains rulership adopts monopolistic tendencies"[16]. Nevertheless, adopting executive strategies grounded in theoretical foundations can minimize these factors.

To achieve this goal, strengthening institutional transparency through the establishment of centralized oversight institutions, leveraging information technology for systematic information dissemination, and promoting universal oversight through discourse-building are essential. Additionally, youth empowerment and elite circulation, as solutions to address administrative stagnation, can reduce corruption risks by fostering dynamism in management systems. These strategies, by combining the creativity of younger personnel with the experience of older individuals, enhance administrative integrity and efficiency. Furthermore, sustained cultural programs, such as events centered on anti-corruption values, can awaken the collective conscience and strengthen public participation in combating corruption.

Ultimately, combating corruption, as a multifaceted endeavor, requires the integration of governmental oversight, public participation, and anti-corruption policymaking. This study proposes a comprehensive framework for preventing and addressing corruption through strategies such as establishing a centralized transparency institution, strengthening universal oversight, and utilizing information technology. Implementing these strategies not only helps mitigate corruption bottlenecks in administrative systems but also fosters public trust and supports the realization of good governance objectives, paving the way for sustainable development and enhancing the legitimacy of governance systems. Achieving these goals requires resolute commitment from governmental institutions, lawmakers, and citizens to the systematic and coordinated implementation of these strategies.

Proposed Solutions and Policy Recommendations: A Comprehensive Framework for Preventing and Combating Administrative Corruption

Based on the theoretical and operational discussions presented in this study, which analyzed corruption bottlenecks and preventive factors, a set of policy measures can serve as a comprehensive strategy to enhance administrative integrity and achieve the objectives of good governance. These measures, grounded in the principles of transparency, meritocracy, universal oversight, and the utilization of information technology, are outlined below with an emphasis on their operational and policy dimensions:

1. Strengthening Oversight of Transparency: Designing and implementing a multi-layered oversight system, including overt inspections by heads of organizations, their deputies, or, in their absence, administrative inspectors, alongside covert inspections conducted in the guise of clients or employees. This mechanism, aimed at assessing performance integrity and identifying violations, can enhance oversight effectiveness through specialized training and collaboration with intelligence agencies. Covert oversight, in particular, plays a key role in preventing corruption by fostering deterrence through "integrity testing."

2. Establishment of the Centralized Transparency Institution for Organizations and Administrations (SHAMSA)[4]: Creating an institution under the supervision of the General Inspection Organization of Iran to standardize and integrate transparency processes across organizations and administrations. With duties such as specialized data analysis, simplifying information for public comprehension, developing standardized information disclosure

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[4] [In Persian]

indicators, and aggregating data directly or indirectly, this institution enhances public access and sustains transparency. Its placement under the General Inspection Organization ensures effective oversight of its performance.

3. Creation of Electronic Administrative Service Offices: Establishing electronic administrative service offices, either independently or as part of electronic judicial service offices, under SHAMSA's supervision, to receive and refer public reports on administrative corruption. These offices, by facilitating reporting without requiring identity verification, encourage public participation and channel citizen demands to a single authority, reducing fragmentation caused by multiple systems.

4. Youth Empowerment and Combining Experience with Creativity in Management: Incorporating age as a factor in selecting managers, emphasizing the integration of young, creative talent with the experience of older managers. This approach mitigates risks associated with gerontocracy and conservatism, fostering dynamism in management systems. Older individuals can contribute to organizational efficiency in advisory roles, such as knowledge management and experience transfer.

5. Promoting Elite Circulation and Organizational Dynamism: Developing policies for elite circulation in administrative systems in collaboration with the Administrative and Recruitment Affairs Organization and the National Elites Foundation. It is proposed to establish a structure called the "Administrative Elites Organization" (SAANA)[5] within the National Elites Foundation to formulate criteria and policies for selecting elites, fostering creativity, and enhancing administrative integrity through diverse work experiences. This strategy prevents corruption bottlenecks by reducing monopolistic tendencies and managerial stagnation.

6. Strengthening the Social Discourse of Anti-Corruption: Promoting universal oversight and public demand through discourse-building in the fight against corruption. This process, utilizing media, anti-corruption policies, and sustained cultural programs—such as competitions centered on anti-corruption themes grounded in religious verses, narrations, and academic resources—awakens the collective conscience and enhances citizen participation in overseeing public institutions. Collaboration with academic and cultural institutions, such as universities and educational centers, ensures the sustainability of this discourse.

7. Leveraging Information Technology: Systematically integrating information technology into bureaucratic processes to expedite, facilitate, and reduce errors and corruption in administrative tasks. This strategy, in collaboration with the Ministry of Information and Communications Technology and the Ministry of Intelligence, can improve public access to information and strengthen transparency through the development of centralized, user-friendly systems. Minimizing human intervention in executive processes reduces the likelihood of abuse and violations.

Implementing these measures requires coordinated commitment from governmental institutions, lawmakers, and citizens. Therefore, the following recommendations are proposed:

- Drafting Executive Regulations: For SHAMSA and electronic administrative service offices, emphasizing transparent processes and operational independence.

- Strengthening Digital Infrastructure: Investing in information technology infrastructure to support transparency and reporting systems.

- Education and Culturalization: Designing training programs for administrative inspectors and citizens to enhance awareness and empower universal oversight.

- Inter-Institutional Collaboration: Establishing a joint committee among the General Inspection Organization, the National Elites Foundation, and the Ministry of Information and Communications Technology to coordinate the implementation of proposed measures.

- These strategies, rooted in the theoretical frameworks of good governance and historical and religious experiences, not only mitigate corruption bottlenecks but also foster public trust, accountability, and citizen participation, paving the way for sustainable development and enhancing the legitimacy of governance systems.

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Smart mesoporous silica nanocarriers in breast cancer treatment

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ABSTRACT

Breast cancer is one of the most common and fatal types of cancer worldwide, requiring innovative therapeutic approaches. Mesoporous silica nanoparticles (MSNs), due to their structural features and unique capabilities—including regular porosity, biocompatibility, and surface tunability—have been recognized as an effective tool for targeted drug delivery. This article explores the smart applications of MSNs in breast cancer treatment. Advantages such as drug-loading capacity, controlled release, and precise targeting enhance treatment efficacy while reducing side effects. However, challenges such as production costs and structural stability remain, necessitating further research.

Keywords: Mesoporous silica nanoparticles (MSNs), breast cancer, targeted drug delivery, controlled release, smart treatment, nanotechnology

INTRODUCTION

Breast cancer, as one of the most fatal and common types of cancer worldwide, necessitates innovative therapeutic approaches that ensure high efficacy with minimal side effects. Recent advancements in material science and nanotechnology have provided unprecedented opportunities for the development of targeted drug delivery systems. Among these, mesoporous silica nanoparticles (MSNs) have emerged as a prominent option due to their unique structural properties and exceptional capabilities.

The distinctive features of these nanoparticles, including uniform porosity, tunable size and shape, and the ability to chemically modify their surface, enable researchers to deliver drugs precisely and effectively to tumor sites. By incorporating smart functionalities, such as sensitivity to specific biological or chemical stimuli, these nanoparticles can respond to environmental changes and release drugs exclusively under specific tumor conditions. This technology not only enhances drug efficacy but also significantly reduces the side effects associated with traditional therapies. However, the application of smart nanocarriers in breast cancer treatment, while offering therapeutic innovations, also faces challenges such as the complexity of production processes, high costs, and safety evaluation concerns. These challenges require thorough investigation and extensive research. The aim of this article is to provide a comprehensive review of the capabilities and limitations of smart mesoporous silica nanoparticles in breast cancer treatment. By focusing on innovative approaches and recent advancements, we strive to gain a deeper understanding of the potential of this technology for clinical applications.

1. BREAST CANCER

Breast cancer, as the most common type of cancer among women, is the second leading cause of cancer-related deaths after lung cancer. This disease is characterized by the uncontrolled growth of breast cells, leading to the formation of undifferentiated masses. Breast cancer is classified into two main categories: invasive and non-invasive. Non-invasive breast cancer typically begins in the milk ducts and remains localized. A prominent example of this type is ductal carcinoma in situ (DCIS). In contrast, invasive breast cancer has the ability to spread to the surrounding breast tissues and includes two common types: invasive ductal carcinoma and invasive lobular carcinoma. One subset of invasive breast cancer is hormone receptor-positive carcinomas (HICs). This type of cancer is identified by the presence of estrogen and progesterone hormone receptors, and its growth depends on these hormones. Therefore, hormonal therapies play a significant role in inhibiting and controlling this type of cancer [1, 2].

The most common physical symptom of breast cancer is the presence of a painless lump. Occasionally, the cancer may spread to the lymph nodes under the armpit, causing a noticeable swelling. Less common symptoms include breast pain or heaviness, nipple abnormalities such as spontaneous discharge (especially bloody), itching and scaling of the nipple, inward retraction and tenderness, orange-peel-like skin texture, and new visible changes such as ulcers, redness, prominent veins, or skin tightening. Diagnostic methods for breast cancer include clinical examination, mammography, ultrasound, and biopsy. Treatment options encompass surgery, chemotherapy, radiotherapy, immunotherapy, and targeted therapies. One of the emerging drug delivery strategies is the use of nanocarriers, which can enhance treatment efficacy and minimize damage to healthy cells. Nanocarriers such as micelles, dendrimers, and magnetic nanoparticles are being utilized in breast cancer therapy [1, 3, 4].

Women with a family history of breast cancer are at a higher risk of developing the disease. A Western diet, characterized by high-fat and energy-rich foods, and reproductive factors such as early menstruation, late menopause, advanced age at first pregnancy, and a low number of pregnancies are also significant risk factors for this type of cancer. The mortality rate associated with breast cancer is high, and its incidence is similar among women in South Asia and developed countries. This is primarily due to limited screening practices, low awareness, and insufficient knowledge about breast cancer. Early detection can be facilitated through mammography and proactive efforts [1, 2].

Traditional cancer treatment methods commonly include surgery, chemotherapy, and radiotherapy. Alongside these approaches, more advanced therapies such as hormone therapy, anti-angiogenic treatments, stem cell therapy, immunotherapy, and dendritic cell-based immunotherapy are gaining traction. In radiotherapy, ionizing radiation is used to destroy cancer cells and reduce tumor size. However, this treatment can also damage healthy cells, tissues, and organs. Chemotherapy, on the other hand, is one of the most effective methods for reducing cancer-related complications and mortality, though challenges persist in minimizing its side effects. More than half of cancer patients undergoing chemotherapy experience severe peripheral neuropathy, known as chemotherapy-induced peripheral neuropathy (CIPN). This condition arises from a group of chemotherapeutic drugs that can harm sensory, motor, autonomic, and even cranial nerves. Symptoms of CIPN typically include numbness, decreased proprioception, burning pain, and hypersensitivity to pain. One of the major challenges in chemotherapy is drug resistance, where cancer cells that initially respond to anti-cancer drugs gradually become resistant. This resistance primarily results from decreased drug uptake by cancer cells and increased drug efflux. Moreover, traditional chemotherapy methods face limitations such as difficulty in determining the optimal dosage, lack of therapeutic specificity, rapid drug metabolism, and severe side effects. The genotoxicity of chemotherapeutic drugs, a key mechanism, leads to tumor cell destruction through the generation of reactive oxygen species (ROS). Meanwhile, hormonal therapies are widely employed to treat malignant cancers. Known as cytostatic treatments, these therapies control and limit cancer progression by blocking hormonal growth factors that stimulate tumor growth [5, 6].

2. NANOCARRIERS

Nanocarriers refer to delivery systems that are one of the innovative methods for targeted drug delivery. They have diverse structures, such as carbon-based, lipid-based, polymeric, and metallic, and are used in cancer treatment due to their unique characteristics. These features enable them to improve drug targeting, efficacy, and controlled release, making them highly effective in delivering drugs directly to tumor sites while minimizing damage to healthy tissues [7]. These nanocarriers, with their small diameter (1 to 100 nanometers) and high surface-to-volume ratio, can easily pass through biological barriers and release drugs in a controlled manner. Nanocarriers possess biocompatible and biodegradable properties, allowing for the loading of biomolecules and overcoming challenges such as chemical resistance and systemic toxicity [8-10].

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2.1-APPLICATION OF NANOCARRIERS IN CANCER TREATMENT

The use of nanocarriers improves the solubility and bioavailability of drugs, enabling them to pass through the blood-brain barrier and other biological obstacles while also preventing damage to healthy cells. This technology enhances the targeting of cancer cells and helps reduce multidrug resistance. For example, the anticancer drug doxorubicin, which has high toxicity, can be more effective and cause fewer side effects when delivered using nanocarriers [11, 12].

One of the main challenges in traditional chemotherapy is the lack of selectivity of the drugs, which affects healthy cells and leads to significant side effects. The use of nanocarriers as drug delivery systems largely addresses this issue by increasing the drug concentration in tumor tissue and reducing its distribution in healthy tissues. One type of these nanocarriers is mesoporous silica nanoparticles. Due to their unique structural properties, these nanocarriers are recognized as effective tools for drug delivery and have shown positive results in cancer diagnosis and treatment [13].

3. MESOPOROUS SILICA NANOPARTICLES

MSNs are a type of solid material with mineral siloxane structures that possess unique and tunable properties, such as a large surface area, pore volume, and surface active groups, low bulk density, controllable nanoparticle size, easy synthesis, and scalability. Due to these characteristics, they are highly regarded for use in various fields such as biological imaging, tissue engineering, vaccine development, adsorption, catalysis, medicine, drug delivery, chemotherapy agent delivery, and cancer treatment [9, 14-19].

These nanoparticles, due to their porous nature, allow for higher drug loading in their structural cavities, enhance solubility, and improve therapeutic activities. The structure of MSNs nanoparticles is hexagonal in two-dimensional form and cubic in three-dimensional form. Other types of MSNs nanoparticles also exist as drug carriers, capable of loading various drug molecules such as proteins and peptides. The regular structure of these nanoparticles prevents the degradation of drugs in the physiological environment. Features such as low cost, minimal toxicity, tunability, and surface functionality make these nanoparticles ideal for enhancing drug delivery applications [15, 20].

MSNs are biocompatible and biodegradable, which enables them to provide multifaceted therapeutic applications. They are also resistant to various stresses, such as pH, mechanical stresses, and heat [16].

The diversity in structure, achieved through various synthesis methods from different sources, the ability to control structure, pore design capabilities, the regulation of nanoparticle size distribution, and the ability to create diverse functional groups on the surface are additional features of MSNs. These characteristics enable the development of various drug delivery systems with high loading capacity [17, 21]. The stimulus-responsive feature of these nanoparticles is due to the presence of both internal and external surfaces, along with organic and inorganic components. This enables precise control over the delivered dose [22].

The surface of MSNs can be coated with specific molecules to ensure that these drug-loaded nanoparticles are precisely delivered to target cells (such as cancer cells). This targeted delivery reduces damage to healthy tissues and enhances the therapeutic effect. In some cases, external stimuli (such as light, magnetic fields, or ultrasound) can be used to trigger drug release. These methods allow physicians to control drug release more accurately and at specific times [23-25].

3.1-APPLICATION OF MESOPOROUS NANOPARTICLES IN BEWAST CANCER

Breast cancer, due to the complexity of disease progression, the biological diversity of tumor cells, and drug resistance, is one of the major challenges in cancer treatment. The use of MSNs in this disease is an innovative and promising approach that, by targeting the tumor precisely and reducing damage to healthy tissues, can significantly improve treatment outcomes. MSNs have the ability to load and release chemotherapy drugs in a controlled manner. For example, doxorubicin, one of the common drugs used in breast cancer treatment, can be loaded into the cavities of these nanoparticles. Then, using smart mechanisms such as pH or specific enzyme triggers in the tumor microenvironment, the drug is released in a controlled manner. This method increases the drug concentration at the tumor site and reduces damage to healthy cells. Additionally, these nanoparticles can specifically bind to overexpressed receptors on cancer cells by attaching specific ligands to their surface Fig. 1.
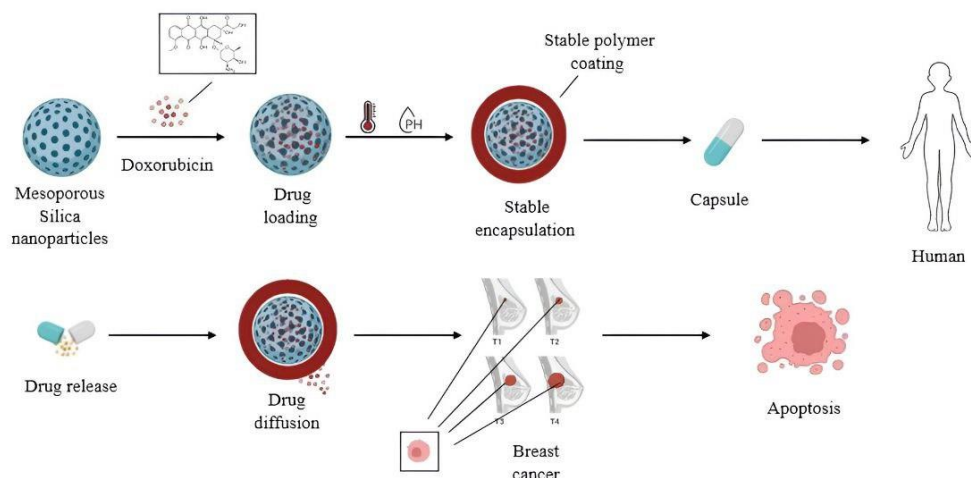
Fig. 1. *This image illustrates the mechanism of loading, transport, and release of the drug Doxorubicin (Dox) using MSNs nanoparticles. After stabilizing the nanocarrier with a polymer coating, the drug is encapsulated and administered in the body. Upon drug release at the site of breast cancer tumors, anticancer effects are triggered, activating apoptosis (programmed cell death) in cancer cells. This technology has the potential to enhance drug targeting and reduce the side effects of chemotherapy.*

For breast cancer, receptors such as HER2, EGFR, and CD44 are key targets. This specific targeting ensures that nanoparticles directly reach tumor cells, preventing inaccurate drug distribution throughout the body. One of the major barriers to effective breast cancer treatment is finding solutions to overcome therapeutic limitations, such as the reduced effectiveness of chemotherapy drugs. MSNs, with the ability to simultaneously carry multiple therapeutic agents, including anticancer drugs and enhancer molecules like siRNA, present an innovative approach to increasing the sensitivity of cancer cells to treatment. Specifically, these nanoparticles can combine chemotherapy drugs with inhibitors of key genes related to cellular resistance, targeting the complex molecular pathways involved in the survival of cancer cells and significantly enhancing the treatment's effectiveness. These nanoparticles provide a novel tool for combining various treatment methods in breast cancer. Among these approaches are chemotherapy and photodynamic therapy. In photodynamic therapy, a light-sensitive agent is used, which, upon exposure to light, initiates the process of destroying cancer cells. MSNs nanoparticles can simultaneously encapsulate both chemotherapy drugs and light-sensitive agents within their structure and release them in a controlled manner at the tumor site. This approach not only reduces the overall drug dosage but also minimizes chemotherapy side effects, such as damage to the bone marrow, gastrointestinal system, and liver. Additionally, MSNs nanoparticles can be used to carry imaging agents, such as fluorescence molecules or contrast agents. This feature enables the integration of precise diagnosis and targeted therapy, allowing doctors to assess treatment progress in real-time and make more informed decisions [23-25].

3.2-NOVEL APPLICATIONS OF MESOPOROUS SILICA NANOPARTICLES IN BIOSENSORS

Beyond their conventional applications in drug delivery and catalysis, MSNs are also utilized in advanced applications such as the development of biosensors for detecting specific molecules like glucose or complex biomolecules. The ability of these nanoparticles to incorporate various functional agents allows for the optimization of their biological properties and enhances their performance in biological systems. Additionally, diverse chemical modifications, such as the use of biocompatible functional groups or polyethylene glycol (PEG), improve the biocompatibility and reduce the toxicity of the nanoparticles, enabling more precise targeting and increased efficacy in biological environments [26].

4. SYNTHESIS OF MESOPOROUS SILICA NANOPARTICLES

There are various methods for synthesizing MSNs, which are chosen based on practical and economic requirements. Different precursors, such as tetraethyl orthosilicate (TEOS) and sodium silicate solution, are used as the primary sources of mineral silica. Sodium silicate, due to its cost-effectiveness and easy availability, is considered a favorable option for the synthesis of MSNs [27, 28].

The methods for producing these nanoparticles include advanced techniques such as flame combustion, chemical vapor deposition (CVD), microemulsion, and chemical deposition. In these processes, the use of surfactants like cetyltrimethylammonium bromide (CTAB) plays a crucial role. These surfactants form micelles, which serve as templates to create uniform pores in the nanoparticle structure, ultimately resulting in a mesoporous structure with consistent characteristics [29].

4.1-FACTORS INVOLVED IN THE SYNTHESIS OF MESOPOROUS SILICA NANOPARTICLES

The calcination temperature and the presence of impurities such as potassium are key factors in the formation and improvement of mesoporous silica nanoparticles. Specifically, the presence of potassium ions can cause aggregation of silica primary particles, directly influencing pore size and uniformity. These factors not only determine the structure of the nanoparticles but also affect properties such as stability, surface area, and the ability to load materials [30].

4.2-PHYSICAL AND CHEMICAL PROPERTIE

MSNs (Mesoporous Silica Nanoparticles) have a fine mesoporous structure with pore sizes ranging from 2 to 50 nanometers and particle dimensions around 10 to 100 nanometers. This mesoporous structure increases surface area and permeability, enabling diverse applications for these nanocarriers. The structure of MSNs consists of two main parts: the internal surface, which is formed by cylindrical pores, and the external surface, representing the entire nanoparticle. The presence of silanol groups on the surfaces of these nanocarriers generates a negative charge, allowing modification with positive charges and improving the nanocarrier's efficacy. These nanocarriers have pores arranged in a regular pattern with a uniform structure, providing a specific surface area ranging from 700 to 1000 m²/g and pore volume between 0.6 to 1 cm³/g. These features allow MSNs to load high amounts of drugs and enhance their dissolution rate, playing a crucial role in optimizing drug delivery treatments [31-33].

The standard honeycomb pore structure is typically formed when strong bases like NaOH are used as solvents. MSNs are primarily synthesized through sol-gel reactions and typically form spherical or rod-like shapes. The final shape primarily depends on the identity and volume ratio of the solvent used during the sol-gel reaction. These factors significantly influence the physical and chemical properties of the final product and can affect the structure and performance of the resulting materials [34].

Biologically-based synthesis methods have also attracted significant attention in the production of MSNs nanoparticles. These methods are generally divided into two main categories: top-down and bottom-up approaches.

TOP-DOWN

In this approach, larger biological materials or structures are broken down into smaller nanoparticles. For example, the use of a ball mill is a common method for grinding raw materials [35].

BOTTOM-UP

In this method, nanostructures are formed by assembling atoms or molecules. This approach allows for more precise control over the size, shape, and uniformity of the final nanoparticle structure [30]. In addition, other methods for producing these nanoparticles include sol-gel, solvent evaporation-induced self-assembly, and methods based on microemulsion.

4.3-SOL-GEL

In the sol-gel method, silica precursors such as tetraethyl orthosilicate (TEOS) undergo hydrolysis and condensation in the presence of surfactants and catalysts. This process results in the formation of a colloidal suspension (sol). In the next step, surfactants act as a template to create mesoporous structures. After the gel is formed, processes such as calcination or chemical extraction are employed to remove the surfactants, yielding the final mesoporous structure. This method is popular due to its simplicity, precise control over structural dimensions, and the ability to use various surfactants. Based on the type of precursors, this method can be divided into two categories: mineral precursors such as chlorides, nitrates, sulfides, and alkoxide precursors like tetramethoxysilane and tetraethoxysilane. This process utilizes the reaction of metal alkoxides and water in the presence of acid or base to form a single-phase solution, which ultimately transforms into a hard two-phase system consisting of solid metal oxides and solvent-filled cavities [36].

4.4-EVAPORATIVE INDUCED SELF-ASSEMBLY (EISA)

In this method, a solution containing silica precursors and surfactants is prepared. With controlled evaporation of the solvent, the concentration of the solution components increases, and the surfactants self-assemble into regular structures such as cylindrical or spherical micelles. These structures act as templates to create mesoporous cavities. After the self-assembly process is complete, the surfactants are removed through calcination (heating) or chemical extraction, leaving behind the final mesoporous structure. This method does not require complex equipment, and its major advantages include high control over the size and shape of the pores and ease of implementation [37].

4.5-MICROEMULSION-BASED METHODS

In microemulsion-based methods, water-in-oil or oil-in-water systems are used as the reaction medium. In these systems, silica precursors dissolve in the aqueous or oily phase, and by precisely controlling reaction conditions such as pH, reaction temperature, and phase ratios, mesoporous nanoparticles with controlled size and shape can be produced. Microemulsions provide an environment with nanoscale dimensions, enabling a precise and uniform self-assembly process. These methods are particularly useful for producing mesoporous materials with specific structures and have diverse applications in nanotechnology, sensors, and drug delivery [38, 39].

Each of these methods, depending on the reaction conditions, type of surfactant, and precursor, can lead to improvements in the physical and chemical properties of nanoparticles and can be significantly used in drug delivery and other biological and industrial applications. The choice of the appropriate method depends on the final application, desired nanoparticle size and shape, and the available equipment Fig. 2.
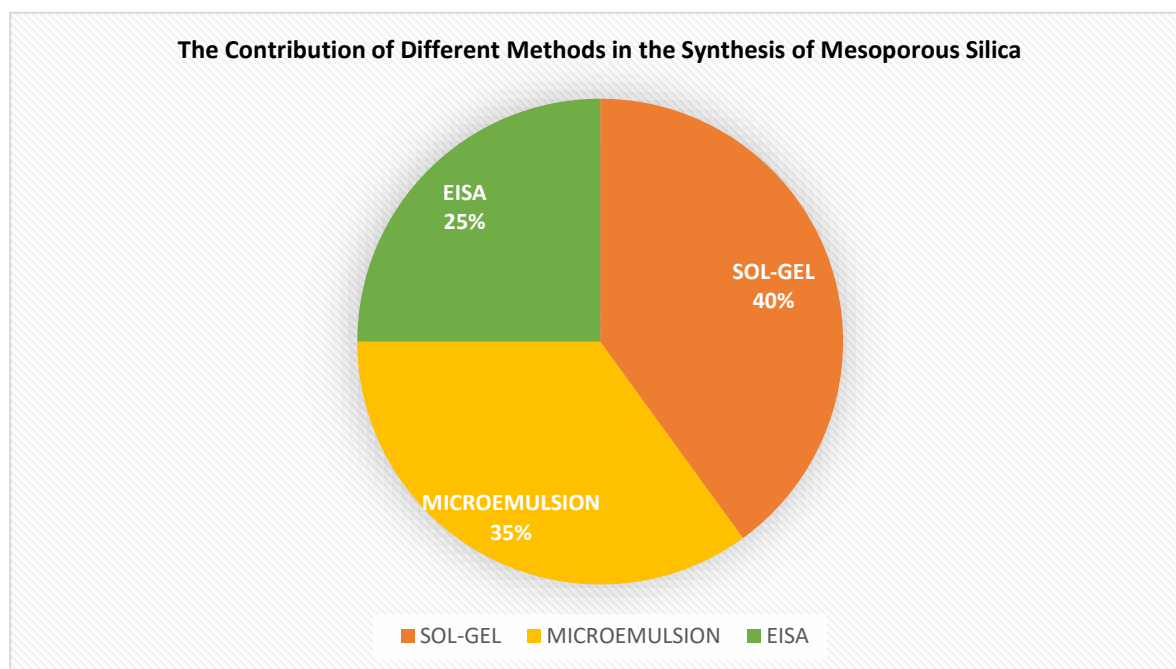

The Contribution of Different Methods in the Synthesis of Mesoporous Silica

Fig. 2. *A pie chart illustrates the approximate contribution of three main synthesis methods for silica: sol-gel (40%), microemulsion (35%), and EISA (25%). These methods are widely utilized in the production of mesoporous silica, each offering unique characteristics and advantages that make them suitable for specific applications.*

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5. DRUG DELIVERY METHODS

Drug delivery systems play a crucial role in optimizing the treatment of many diseases, especially cancer. The goal of these systems is to enhance the therapeutic efficacy while minimizing side effects. In recent years, significant advancements have been made in the design and development of drug delivery methods. These methods include smart drug delivery, targeted drug delivery, controlled drug delivery, and on-demand drug delivery.

5.1-SMART DRUG DELIVERY

Smart drug delivery systems are designed to deliver drugs in a controlled and targeted manner to diseased organs. These systems are developed to reduce the side effects of drugs and enhance their therapeutic efficacy. The key feature of these technologies is their ability to be programmed and adapted to the specific environmental conditions of the injury site, so that the drug is not released until it reaches the target tissue, or it is released at a very low rate. At the target site, the drug is released at an appropriate rate and amount. Smart nanoplatfoms play a crucial role in the development of these systems due to their unique characteristics. These platforms release drugs selectively at the damaged site using endogenous triggers such as pH changes, enzyme concentration, and redox gradients, or exogenous triggers such as temperature, magnetic fields, and light. These features not only increase drug concentration at the target site but also minimize drug toxicity to healthy tissues. The advantages of smart drug delivery systems include reducing fluctuations in drug concentration in the bloodstream, releasing drugs at the correct amount, prolonging the duration of the drug's presence in the target tissue, and improving therapeutic efficacy. Moreover, these systems can deliver drugs intracellularly due to their high targeting potential. Nanoparticles, as the key components in designing these systems, offer high surface-to-volume ratios, surface modification capabilities, and the ability to load various molecules, making them ideal smart carriers. These nanomaterials, through precise drug release control, play a significant role in increasing safety and therapeutic efficacy. Therefore, the use of nanotechnology in smart drug delivery systems offers a promising outlook for improving current therapeutic methods [40].

5.2-TARGETED DRUG DELIVERY

Targeted drug delivery, especially in the treatment of complex diseases such as cancer, has always been one of the major challenges in medicine. Additionally, an ideal drug delivery system should minimize the adverse effects of the drug while maximizing its beneficial effects. Among various drug delivery systems, targeted systems are recognized as a preferred and more efficient option, utilizing nanoparticles or other materials to deliver the drug to the precise site of action [41]. This drug delivery system has gained attention as one of the promising approaches to improving both efficacy and safety. Recent advancements in drug delivery technologies have enabled the development of personalized therapeutic strategies for cancer patients, offering tailored treatments that are more effective and better suited to individual needs [42].

Nanoparticles are widely used as effective carriers for chemotherapy drugs, nucleic acids, and genes to specific target sites, particularly for the treatment of oncological diseases. The tumor microenvironment (TME) plays a crucial role in tumor progression and consists of tumor cells, tumor stromal cells, extracellular matrix, and various types of cytokines and chemokines [43]. The combination of nanotechnology, biomaterials, and molecular targeting strategies has enabled the development of complex drug delivery systems that selectively deliver therapeutic agents to tumor tissues while minimizing negative effects on healthy tissues. Various targeting mechanisms, including passive and active targeting strategies, rely on specific physiological characteristics of tumors, such as abnormal vasculature, overexpressed receptors, and changes in the tumor microenvironment, to ensure drug accumulation and retention in the target tissues. Nanoparticle-based drug delivery systems, such as liposomes, polymeric nanoparticles, and inorganic nanoparticles, have become attractive options for targeted cancer therapies due to advantages like high drug loading capacity, stable release, and precise tumor targeting [42]. Starch-based nanoparticles have also gained attention in biomedical research, and their unique characteristics, such as small size, high surface-to-volume ratio, and biocompatibility, make them ideal candidates for targeted therapies. These properties enable starch nanoparticles to efficiently deliver therapeutic agents, offering potential advantages in drug delivery and other biomedical applications [44]. Zein, a nanocarrier derived from the prolamin class of corn, is a hydrophobic biological macromolecule that has shown great potential as a versatile nanocarrier. One of the advantages of this protein is its ability to successfully load hydrophobic drugs onto nanoparticles. Zein is a natural, edible, and biocompatible protein with unique properties that make it suitable for use in drug delivery systems. It has a high degree of hydrophobicity, which allows it to efficiently encapsulate hydrophobic compounds and provides chemical and thermal stability, making it resistant to degradation in food systems. However, the ability to effectively encapsulate hydrophilic drugs in zein nanoparticles remains a critical challenge [45].

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5.3-CONTROLLED DRUG DELIVERY

Controlled drug delivery systems in breast cancer treatment, particularly using smart mesoporous silica nanoparticles, have gained a prominent place as one of the most advanced methods of targeted therapy. These nanoparticles are designed so that drugs are released in response to specific environmental conditions, such as changes in pH, temperature, or chemical compounds in the tumor microenvironment. This feature enables the precise and regulated release of both hydrophobic and hydrophilic drugs, playing a crucial role in improving the effectiveness of breast cancer treatment. One of the main advantages of controlled drug delivery systems is the reduction of side effects. Due to the local release of the drug at the target site, damage to healthy tissues is prevented. Additionally, these systems release the drug gradually over extended periods (from weeks to months), reducing the need for frequent dosing and constant visits to the doctor. This feature not only increases patient compliance with treatment but also provides greater convenience for the patient. However, controlled drug delivery systems also face challenges. Most of these systems depend on external environmental factors, such as pH or specific enzymes, to control drug release. This dependency may not result in optimal performance in some patients due to variations in the disease microenvironment or individual conditions. Moreover, once the drug delivery system is in the body, adjusting the timing or amount of drug release is generally not possible. The Spensule technology is one of the innovative advancements in controlled drug delivery, designed to control the drug release rate, allowing drugs to be effective for longer periods (up to 12 hours). In this technology, the drug is encapsulated in small capsules, each with multiple layers of coating materials. These layers are designed to dissolve gradually in the body (stomach or intestines), slowly releasing the drug. The standout features of this technology include controlled, pre-determined drug release rates, allowing the drug to be taken only once or twice a day, which helps maintain a consistent drug concentration in the blood and improves the comfort and effectiveness of treatment for patients. Spensule technology is recognized as a major breakthrough in stable release formulations and represents an important step forward in the development of advanced drug delivery technologies. This innovation has paved the way for the creation of more complex drug delivery systems. Despite these challenges, controlled drug delivery continues to be one of the most powerful tools in enhancing breast cancer treatments, and significant efforts are being made to optimize this technology [46].

5.4-RELEASE ON DEMAND TECHNOLOGY

Recent research has shown that advanced drug delivery systems leverage novel materials and fabrication technologies to provide stronger approaches for tackling both acute and chronic diseases. Unlike traditional drug carriers, which were only able to control the uniform release of drugs, modern drug delivery technologies offer more precise control over the timing and amount of drug release. To achieve this goal, methods such as "programmed" and "on-demand" systems have been introduced. In programmed methods, drug delivery systems are designed with complex architectures to regulate the drug release rate over a specified period. In contrast, on-demand methods involve systems that can be directly controlled by an operator or physician. This control can be achieved through a remote device that stimulates the implanted or injected drug carrier, activating drug release. These technologies enable the creation of flexible drug release patterns and enhance treatment efficacy through precise control over the timing, duration, dose, and site of drug release. Such systems, with high reproducibility and reliability, represent an important step in personalizing treatment. Additionally, advanced techniques like 3D printing have been employed in the fabrication of these systems, providing further capabilities for remote control and fine-tuned drug delivery. These technologies have opened new horizons for more targeted and efficient treatments [47, 48].

6. DRUG LOADING

MSNs drug carriers, due to having two functional surfaces that can selectively conjugate agents, can enhance drug interactions and improve its release. Given their porous structure and high surface area, these nanocarriers are considered important options for drug loading. Drugs are loaded into the mesopores of these nanocarriers in an amorphous form, which increases the rate and extent of drug release in the body [49].

The drug loading methods in MSNs nanocarriers are generally divided into two main categories: solvent-based methods and solvent-free methods.

SOLVENT-BASED METHODS

In these methods, solvents like ethanol or supercritical CO_2 are used to dissolve the drug and introduce it into the mesopores. The solvent is then carefully removed, leaving the drug inside the pores. These methods are particularly suitable for loading heat-sensitive drugs, such as proteins and nucleotides, as they minimize degradation due to the use of low temperatures. However, these methods require precise control of the filling process and multiple steps [31, 49].

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SOLVENT-FREE METHODS

These methods include techniques such as melting and impregnation. The drug is introduced into the nanopores in its molten or solid state. These methods are simpler and faster but may not be suitable for heat-sensitive materials. In the adsorption method, nanoparticles are immersed in a concentrated drug solution, and the drug is adsorbed onto the inner walls of the pores. The nanoparticles are then dried. This method is commonly used due to its simplicity and low cost, but it may require a high drug concentration, which can lead to pore blockage and reduced loading efficiency. For example, drugs like ibuprofen can easily be loaded into nanoparticles in an amorphous state. In contrast, itraconazole, due to its high viscosity in the molten state, cannot penetrate the pores and instead accumulates on the surface of the nanoparticles, resulting in slower drug release [31, 49].

7. DRUG RELEASE

Nanomedicine drug delivery systems are among the best methods for drug delivery, offering unlimited possibilities for transporting drugs. In nanocarriers, the surface-to-volume ratio is higher, so at the same concentration, a larger surface area of the drug comes into contact with the body. As a result, the drug dose is reduced, minimizing side effects and toxicity. Various forms of nanocarriers, such as dendrimers, liposomes, rods, and many others, serve as effective drug carriers. These different forms of nanocarriers are versatile and can absorb or trap drugs, dissolve them at the surface of the nanocarriers, and ultimately work effectively in drug targeting. As mentioned, the main task of nanocarriers is to deliver drugs to specific locations. Processes like passive diffusion, phagocytosis of particles, pinocytosis, or endocytosis help transfer drugs via nanocarriers to cells through receptors. This drug delivery method can be done via active or passive targeting. In tumors, the enhanced permeability of blood endothelial vessels is used to facilitate the delivery of drugs by nanocarriers to tumors, known as passive targeting, which results in a longer exposure time of the drug to the tumor. In active targeting, nanocarriers use specific targeting ligands on their surface to target cancer cells, which have specific receptors on their surface. Using these methods helps reduce drug side effects and also decreases cellular resistance to the drug [50-53].

These nanocarriers are used to improve colloidal stability and protect therapeutic molecules from degradation, as well as to enhance drug absorption at target sites. Additionally, nanoparticles have been shown to improve therapeutic effects and reduce side effects [13, 54-56].

8. CHALLENGES AND LIMITATIONS

The use of MSNs (Mesoporous Silica Nanocarriers) in drug delivery and other biological applications offers many benefits, but it also comes with challenges and limitations, including limitations in drug loading, structural stability, high costs, and complexity in design and mass production [13, 54-56].

One of the main goals of nanocarriers is the precise release of drugs at the target site. However, achieving perfect accuracy in drug release, especially in the complex environments of the human body, can be challenging. Without proper control, the improper release of drugs can reduce the effectiveness of treatment or cause unwanted side effects. This challenge is especially significant when designing nanocarriers for cancer treatment, as targeting cancer cells precisely and releasing the drug only at the tumor site is essential for the success of the therapy. Moreover, structural and biological differences between various cancer cells and healthy cells, particularly in individual-specific tumors, can make it difficult to accurately identify cancer cells. This issue calls for the development of more intelligent systems that can specifically respond to the unique characteristics of tumors. MSNs are known for their good stability due to their structural features, but this stability may decrease under in vivo conditions and during long-term treatments. Therefore, improving the performance of these carriers and extending their effectiveness without degradation or damage to healthy tissues is another issue that requires special attention. Despite these challenges, scientific advancements in this field can significantly enhance the effectiveness of targeted cancer therapies. In the development of MSNs as targeted treatments for breast cancer, there are barriers that hinder the rapid commercialization of this technology. One of these barriers is the cost and complexity of large-scale production. The intricate processes and the need for precise quality control in manufacturing nanocarriers can be expensive, which may present difficulties during the commercialization stages. Therefore, research needs to focus on methods to reduce costs and facilitate mass production. In addition, cancer cells' resistance to chemotherapeutic drugs can also reduce the effectiveness of treatment. Smart nanocarriers must be designed to effectively deliver different drugs to target cells and prevent drug resistance. This issue requires extensive research into simulating and studying cellular responses to different drugs to provide appropriate strategies to counter drug resistance. Moreover, precise drug release specifically targeting cancer cells while protecting healthy cells from the side effects of chemotherapy drugs remains another important issue. The design of nanocarriers must ensure that healthy tissues are protected and only cancer cells are targeted. This requires more sophisticated designs that are still under research and development. Despite the scientific progress in the field of nanocarriers, there are still obstacles in fully harnessing this technology for breast cancer treatment. Overcoming

these challenges requires further research and innovation in the design, production, and application of these nanocarriers [57, 58].

9. FUTURE RESEARCH AND DEVELOPMENT

The future of research and development in the field of smart MSNs nanocarriers for breast cancer treatment is full of innovation and new opportunities. One of the main challenges is improving the targeting accuracy of these nanocarriers to better identify and treat cancer cells. The use of smart materials that can detect environmental changes and release drugs in a targeted manner could enhance treatment efficacy and reduce side effects. Additionally, research focused on the precise control of drug release timing and location, as well as improving the safety profile of nanocarriers, is of great importance. Mass production and cost reduction are also key priorities for commercializing this technology. Ultimately, advancements in clinical simulations and precise modeling could help accelerate the transfer of this technology from the laboratory to clinical treatments. By addressing these challenges, smart nanocarriers could become a more effective tool in the treatment of breast cancer.

CONCLUSION

MSNs nanoparticles have shown great potential in breast cancer treatment. These nanoparticles, with the ability to load various drugs, enable smart drug release, and reduce side effects, can significantly improve therapeutic approaches. However, for commercialization and widespread use, optimization of production methods, cost reduction, and further research on the safety and stability of these nanoparticles are necessary. Future advancements in this field may lead to more effective and personalized treatments.

APPRECIATION

At the end of this article, we feel it is essential to express our sincere appreciation and gratitude to Ms. Negar Nasri for her unparalleled support and guidance throughout this journey. With her valuable knowledge and experience, she has consistently motivated and inspired us, playing a crucial role in helping us achieve our goals. We hope to continue benefiting from her expertise and experience in the future. With respect and best wishes for her continued success.

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Obsessive-compulsive and related disorders

Soraya Nazarpour Melai

Abstract

Obsessive-compulsive disorder (OCD) is a common, chronic, anxiety disorder that can have debilitating effects on both genders throughout the patient's lifetime. OCD can present with a wide range of clinical manifestations. This disorder is one of the most debilitating anxiety conditions and accounts for more than half of all cases of serious anxiety. The broad spectrum of OCRD Includes somatic disorders (eg, body dysmorphic disorder (BDD) and hypochondriasis), impulse control disorders (eg, trichotillomania (TTM), pathological gambling, skin picking, etc.), and tic disorders (eg, Tourette syndrome) but others, including drug-induced disorders and non-psychiatric disorders, can overlap and show similar clinical manifestations. The purpose of the present study Is to provide a comprehensive and up-to-date resource on obsessive-compulsive disorder (OCD) and obsessive-compulsive-related disorders (OCRDs) and their clinical management through literature review and analysis. This study Is a type of secondary studies and Its implementation method is a systematic review.

Keywords: Obsessive-compulsive disorder, OCD-related disorders, OCD, OCRDs

Introduction

Obsessive-compulsive disorder OCD is classified In the revised version of the Diagnostic and Statistical Manual of Mental Disorders as an anxiety disorder In which a person experiencees disturbing and repetitive thoughts, mental images or impulses, which are defined as obsessive thoughts. The following repetitive behaviors that aim to reduce anxiety associated with obsessive thoughts are called obsessive actions. The diagnostic criteria for obsessive-compulsive disorder indicate that obsessive thoughts and actions cause significant anxiety, are time-consuming, and interfere with a person's daily functioning. Also, the person suffering from obsession recognizes to some extent that obsessive thoughts and actions are extreme and illogical. Obsession has the same prevalence in men and women, and its lifetime prevalence is about 2.5% [1].

Obsessive compulsive disorder (OCD) occurs worldwide with common characteristics among different ethnic groups and cultures. As mentioned, It affects approximately 2.5% of the population and Is associated with significant social, personal, and work impairments. In fact, the World Health Organization has identified OCD as one of the top 20 causes of life years with disability for people aged 15 to 44. Although generally longitudinally stable, OCD Is known for considerable heterogeneity, as symptom manifestations and patterns of comorbidities can vary significantly across individuals. In addition, a number of other psychiatric and neurological disorders share similar phenomenological features, can co-occur with OCD, or are sometimes even thought of as atypical manifestations of OCD. These include preoccupations and repetitive behaviors found in hypochondriasis, Tourette syndrome, Parkinson's disease, catatonia, autism, and in some people with eating disorders (such as anorexia nervosa). These heterogeneous aspects of the disorder have led to the search for subtypes of OCD that may be associated with different causes or treatment responses. [2-5]

Ruminating, obsessive mental torments, accompanied by constant ritualistic compulsions, are depicted in biblical accounts as well as Greek tragedies and Shakespeare. In modern nosology, a number of different approaches have been proposed to describe this syndrome. Currently, the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) classifies OCD as an anxiety disorder.

Given that Information about OCD and OCRD, their clinical phenomenology and etiology, may lead to a better understanding of their management.

It Is worth noting that he examined a wide range of OCD disorders, because this is a basic Issue in current clinical psychiatry, according to the aforementioned need, in the present research, an attempt has been made to deal with obsessive-compulsive disorder and related disorders.

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Method

This study Is a type of secondary studies and Its implementation method is a systematic review. In the present study, articles related to obsessive-compulsive disorder and disorders related to obsessive-compulsive disorder were searched In domestic databases from 1390 until now and In foreign databases from 2000 until now. In the database, the keywords of obsessive thought and practical obsession, OCD and OCRDs were used to search for articles. In the search based on keywords, 218 Initial results were obtained. Then, according to the title and abstract of the articles and based on the Inclusion and exclusion criteria, finally 12 related articles were Included in the study. According to the inclusion criteria, articles that investigated obsessive-compulsive disorder and disorders related to obsessive-compulsive disorder were included In the study. According to the exclusion criteria, duplicate articles and articles that did not address the discussed issue well were excluded from the study.

Obsession – practical

 Obsessions are recurrent and persistent thoughts, impulses, or images that are experienced at one time during the disorder, are considered intrusive and inappropriate, and cause marked anxiety or distress. Thoughts, impulses, or images that are not simply excessive worries about real-life problems. The affected person tries to Ignore and suppress such thoughts, impulses or images or neutralize them with anotherr thought or action. Recognizing by the affected person that the obsessive thoughts, impulses, or Images are a product of their own mind rather than imposed from outside. [3_2]

 Compulsions are repetitive activities (eg, washing hands, ordering, checking) or mental acts (eg, playing games, counting, repeating words silently) that a person feels compelled to do In response to an obsession or rigid rules. which must be strictly enforced, they have to do It. Behavior or mental actions intended to prevent or reduce distress or avoid some feared event or situation, but are obviously excessive or lacking in a realistic way to relate to what they are designed to neutralize or prevent. At some point In the course of the disorder, the obsession or compulsion Is excessive or irrational, recognized by the sufferer (unless it Is a child). [8]

 An obsession or compulsion that causes significant distress, is time-consuming (lasting more than 1 hour per day), or significantly Interferes with the person's normal routine, occupational or academic performance, or usual social activities or relationships.

The most commonly identified factors of obsessive-compulsive disorder include four factors :

(1) Obsession with pollution and compulsion to clean up .
(2) Aggressive, sexual, religious, and physical obsessions with checking compulsions ;
(3) Obsessions with symmetry, accuracy, and the need for things to be "just right" with compulsions to order, and count, and
(4) Hoarding obsessions and compulsions. [9]

Historical background

 Obsessive thoughts and compulsions are part of everyday life. We go back to check we've locked the door and turned off the light. We can't help but think about the stressful event planned for next week. We refuse to eat with a spoon that has fallen on the floor, even If we know that the possibility of contamination is unlikely. These events are part of the normal feedback and control loop between our thoughts and actions and have ancestral biological survival value. Only when the obsessive thoughts become frequent or intense, or unavoidable, or when these compulsions become so prominent that they Interfere with a person's functioning, Is a diagnosis of OCD given. [11]

Descriptions of obsessive-compulsive phenomena can be found in historical documents over the past few centuries, as OCD has a long history. A section of the Malleus Maleficarum, a fifteenth-century compendium of witchcraft and psychopathology, describes a priest brought to Rome for an exorcism:

" When he passed through every church and paid homage to the Holy Virgin, the devil forced him to stick his tongue out of his mouth; when he tried to pray, [the devil] attacked him more violently".

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People who had obsessive thoughts of a blasphemous or sexual nature were thought to be partially possessed by Satan, while "psychotic" people appeared to be completely possessed. The 17th-century obsession with guilt-induced handwashing was immortalized by Shakespeare's Lady Macbeth:

[...]" It is a habitual practice with him, it seems that he washes his hands. I know he goes on doing this for a quarter of an hour. [10]

Over time, the explanation of obsession and compulsion was transferred from a religious perspective to a medical aspect. Obsessions and compulsions were first described in the psychiatric literature by Squirrel In 1838, and by the end of the 19th century, they were generally considered manifestations of melancholia or depression. At the beginning of the 20th century, the perspective of obsessive-compulsive phenomena had begun to shift OCD towards a psychological explanation. Janet had already described the successful treatment of ritual compulsions by well-known behavioral methods, and with the publication of Freud's Case Psychoanalysis of Obsessional Neurosis In 1909, Obsessive-Compulsive Acts concluded. Be seen as the results of unconscious conflicts and isolation of thoughts and actions from their emotional components. Although this change was successful in demonstrating that actions can be triggered by factors of whichh the individual is unaware or unable to control, It did little to improve the outcome of OCD patients. [12]

In the 1950s, with the advent of behavior therapy, learning theories that were useful In conceptualizing and treating phobias were applied to OCD symptoms. Although these learning theories are clearly insufficient to explain all symptoms of OCD (as well as OCRD), in the late 1960s and early 1970s they led to the development of effective treatments to reduce compulsive rituals. During the 1980s, research focused on the relationship between OCD and neurological problems such as epilepsy, memory disorders, and Tourette syndrome, while Westphal's early observation of a link between obsessions, tic disorders, and epilepsy anticipated recent neurobiological findings in OCD. Did [13]

While most psychiatrists generally agree on the spectrum of OCD Including anxiety and phobia manifestations, a greater number focus on the need for a clear definition of anxiety and obsessional symptoms, as envisioned in the DSM-V research agenda. . In fact, anxiety phobia is different from OCD. Both phobic and obsessive-compulsive individuals typically avoid fearful objects and generally maintain an awareness that their fears and avoidance behaviors are excessive. People with phobias are usually more distressed at the prospect of actual contact with the thing they fear and will do anything to avoid It. [14]

Epidemiology

Obsessive-compulsive symptoms are common, and not all may count as full-threshold OCD. Approximately 50% of the general population engages in some form of ritualistic behavior, while up to 80% experience intrusive, unpleasant, or unwanted thoughts.

The 1-month prevalence of adult OCD is about 0.6%, while the 12-month DSM-IV prevalence ranges from 0.6% to 1%. Regardless, the prevalence of OCD as well as OCRD may vary depending on the data source and choice of diagnostic tools. Many OCRDs may coexist with each other and with OCD. Regarding physical disorders, the prevalence of hypochondriasis in the general population is 1-5% and among primary care outpatients is 2-7%.

Unfortunately, the prevalence of BDD is difficult to estimate, but estimates range from 0.7% to 2.3% In the general population and at least 6% to 15% in plastic surgery. For OCRD, the prevalence of Tourette's is 0.1%, while the exact lifetime prevalence of TTM is unknown, but rates of 1% to 2% have been reported for cases meeting full threshold diagnostic criteria. [13]

There appears to be an age of onset for OCD. The average age of onset Is reported to be 19 years (21% of cases appeared by age 10), while the average age for adult OCD is between 22 and 35 years. In a small number of cases, the onset of this disorder occurs at the age of 50 or more. Generally, the earlier the age of onset, the worse the course of OCD and OCRD. In contrast, no gender-specific predominance has been reported in epidemiological studies of large samples. This recent evidence contrasts with non-OCD anxiety conditions, where gender ratios typically show a female prevalence. [14]

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While economic, social, and cultural influences may play a role in producing the various clinical manifestations of OCD, biological, immune, and genetic factors and family predisposition may also play a role in the pathogenesis of this disorder. For example, streptococcal infection may be associated with an early-onset, exacerbating-forgetting type of OCD called pediatric streptococcal-associated autoimmune disorder (PANDAS), but little is known about this condition, and particularly about Its pathogenesis. There is a disease.

The fact that many people do not seek appropriate early treatment may be due to stigma, but also due to other factors. Sometimes patients do not realize that they are affected by OCD. In some cases, the "typically obsessive" features of intrusive feelings and thoughts, "dystonic self," are absent, such as in obsessive-compulsive disorder with poor insight (PI-OCD), which complicates the course and severity of the Illness, including PI-OCD and other Subtypes extend the range of cases of OCD, whichh is reported to affect approximately 2% to 3% of the world's population. These show varying degrees of severity and chronic course and often include feelings of depression (80%), major depression (MD) (30%), and Tourette's syndrome (5%). [16]

In addition, OCD patients often exhibit symptoms similar to those of affected relatives. About 8% of first-degree relatives have OCD, while the first symptoms occur in the 20s In 75% of patients. This may occur suddenly or slowly, generally showing an episodic course. Interestingly, the episodic course is sometimes an overlapping feature of the disease with MD, but It may prompt clinicians to consider other affective disorders as well, and we should be more aware of largely unrecognized entities such as cyclothymic-OCD. We encourage [14]

Diagnostic criteria

 The main feature of OCD Is obsession and compulsion. According to the DSM-IV-TR, obsessions and compulsions cause significant distress, are time-consuming (usually lasting more than 1 hour per day for a month or more), and significantly impair the subject's normal functioning. . If another focal disorder is present, it is Imperative that the content of the obsessions or compulsions is not limited to it (eg, preoccupation with food or weight In eating disorders or guilt ruminations in the presence of a major depressive episode (MDE)). The disorder must not be due to the direct effects of a substance (eg, drug or medication abuse), or a general medical condition.

 Obsessions may also present with highly heterogeneous clinical pictures (eg, religious strictness, aggressive or intrusive thoughts, inappropriate sexual thoughts, preoccupation with symmetry and perfectionism, morbid doubt, worry about contamination, morbid hoarding). , while compulsions are defined as repetitive behaviors or mental acts (eg, washing, counting, checking, ordering, touching, cleaning, hoarding, performing mental or physical rituals).

Obsessions are usually unwanted, unavoidable, intrusive, self-dystonic, sometimes fearful or violent (eg, the urge to jump In front of a car, thinking you might attack your spouse, a child's drawing might offend), and often It disrupts performance and quality of life.

It Is noteworthy that most OCD patients criticize their thoughts and hate doing any of their work, but In most cases they are unable to stop such thoughts or behaviors. However, OCD patients can ruminate endlessly ("Did I lock the door?") and most develop compulsions to ward off unwanted events or satisfy obsessions (eg, an obsession with dirt that leads to hand washing). [12]

 Differential diagnosis and clinical phenomenology

 The word "obsession" Is derived from the Latin "obsidēre" which means "to possess", "to possess". In fact, most OCD patients relate to the experience of a medieval castle besieged by strong enemies that must be surrendered without any possibility of escape. The Latin word "comellere" means "to be restrained" and "to be overcome": OCD patients are forced to act on compulsions to overcome obsessions.

 Most OCD patients exhibit both, but sometimes they may exhibit only obsessions or compulsions. This is sufficient regardless of the diagnosis of OCD.

 Up to 20% of cases of major depression have obsessive-compulsive symptoms, and treatment may be the same, while schizophrenic patients often present with idiosyncratic symptoms that they are usually comfortable with, such as schizoaffective disorder (SOD), whichh is a psychopathology of neurological soft symptoms (NSS). It shows that It is a severe form of this disease.

Differential diagnosis Is also a concern due to current OCD and OCRD classification methods. People sometimes wonder if compulsive eating, gambling, shopping, or sexually deviant behaviors are forms of OCRD. Usually, these disorders are not classified as OCRD becausee some enjoyment is gained from these activities and the person usually does not want to stop them, except for the secondary problems they may cause (such as obesity, drunk driving convictions, gambling, etc.). Credit card debt and criminal prosecution for sexual deviance). However, a small number of people with these compulsive behaviors may respond to pharmacological and behavioral treatments that are effective for OCD.[16]

Obsessions are usually accompanied by a heightened "anxious tension" before the compulsions (both behavioral and mental), followed by a brief sense of relief during the compulsions. This type of feeling Is also particularly evident in many OCRDs, as many eating disorders (Eds) may also be considered. In fact, many bulimia nervosa (BN) patients experience a brief reaction after overeating, while anorexia nervosa (AN) patients somehow enjoy being able to avoid food.

It Is important to distinguish between obsessive-compulsive symptoms in the course of Eds and OCD symptoms. A distinction should also be made for the feelings of "anxiety" experienced during the ICD period during compulsion. Sometimes OCD thinking Is strange, and patients can even display features of schizotypal personality disorder (SPD) that they are usually unaware of (eg, "My wife will leave me If I don't get to the elevator"). Becausee the phenomenology of the OCD spectrum may be heterogeneous, many scales and rating tools, such as the Yale-Brown Obsessive Compulsive Scale (Y-BOCS) and others that assess OCRD, have been developd to assist clinicians In diagnosing and scoring symptoms. . But a clinical interview by a trained psychiatrist should not be ruled out in any serious case. [15]

·   **Disorders associated with OCD**

There are several conditions that have features of obsessive-compulsive disorder that closely resemble OCD, such as PANDAS, body dysmorphic disorder (BDD), hoarding disorder, trichotillomania, compulsive skin picking, hypochondria, and olfactory reference syndrome. Many of these disorders are primarily treated with cognitive behavioral therapy.

People with OCD may also have other mental health conditions, such as depression, attention-deficit/hyperactivity disorder (ADD/ADHD), anxiety, Asperger's syndrome, eating disorders, and Tourette's syndrome (TS).

Hoarding disorder

Hoarding disorder Is defined by the acquisition and Inability to discard worthless Items, even if they have no value (to others). People with compulsive hoarding syndrome may have a hard time throwing away anything from the oldest paper clip, to a used food container, to outdated newspapers, for fear that they may need those items in the future. If they have any doubts at all about the value of an object, no matter how insignificant, they keep it "just In case." Animal hoarding is when a person has more pets than they can handle and denies this inability. When a person struggles with animal hoarding, their inability to provide food, shelter, and veterinary care may be seen through the animal.

Pandas

PANDAS, also known as pediatric autoimmune neurodegenerative disorder associated with streptococcal infection, usually occurs before puberty. PANDAS may occur when a child suddenly and severely develops OCD or tic-related symptoms following a strep infection. Symptoms seem to come on very suddenly and may cause the child to become obsessive, compulsive, nervous, moody, irritable, or anxious.

Trichotillomania

Trichotillomania is a condition that causes a person to pull hair from the scalp, eyelashes, eyebrows or any other part of the body. Hair is often pulled In an attempt to reduce anxiety. It varies in severity and may cause bald spots.

Body deformity disorder

Those who struggle with BDD feel disgusted with their bodies. In fact, the claimed defect may be a minor defect or even non-existent. For the person with BDD, the impairment is significant and projective, often causing severe emotional distress and difficulties in daily functioning .

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Skin peeling

Skin picking disorder (SPD) causes sufferers to constantly touch, scratch, or pick at their skin. This may be done In an attempt to remove small irregularities or imperfections. This procedure may leave a scar and can even cause tissue damage or worse. These actions may occur as an attempt to eliminate feelings of fear or anxiety. People may spend hours combing their hair or skin.

Olfactory reference syndrome

People with olfactory reference syndrome (ORS) have an irrational fear or belief that they are emitting a foul or unpleasant body odor, even though they are not. People with olfactory reference syndrome respond to this preoccupation by repeatedly doing certain things, such as showering excessively, brushing their teeth, or smelling themselves. They may also think that others are sitting further away, or that other people's behaviors, opinions, or actions are a direct result of their imagination. This belief causes discomfort, embarrassment and shame and can significantly Impair social relationships as well as a person's ability to function professionally. People with ORS may isolate themselves socially and develop social phobia.

OCD-related disorders based on environmental causes

Three examples of full-blown OCD that appear to occur acutely following possible causative events are:

(1) OCD related to an infection such as Infections associated with streptococcal infections (Pediatric Autoimmune Neuropsychiatric Disorders Associated with Streptococcal Infections Syndrome [PANDAS]) .
(2) Trauma-related OCD following acute brain injuries. And
(3) Occurrence of OCD during the treatment of schizophrenia with atypical neuroleptic agents .

These appear to form an etiologically based OCD subgroup, as most cases of primary and idiopathic OCD have an insidious onset with gradual development of symptoms and impairment over a longer timescale of months or years. [13]

OCD and Infections: an example of PANDAS syndrome

One potential environmental factor in the development of OCD, particularly in childhood, is a suspected relationship between group A streptococcal infections and the onset of OCD and/or tic/tourette syndrome, similar to the development of Sydenham's chorea previously reported following streptococcal infection. . In fact, an increase In the prevalence of obsessive-compulsive symptoms and OCD has also been observed in patients with rheumatic fever (RF) with or without Sydenham's chorea. Initially, these findings were reported in children in the active phase of rheumatic fever. Subsequent studies have shown the presence of OCSD in adults with a previous history of (inactive) rheumatic fever, suggesting that streptococcal infection may cause OCD, which may persist throughout life regardless of rheumatic fever activity. Recent family studies have reported that OCSD and OCRD (such as tic disorders, body dysmorphic disorder, trichotillomania, grooming behaviors, and others) are more clustered in first-degree relatives of rheumatic fever patients compared to controls. In addition, two polymorphisms in the promoter region of the tumor necrosis factor alpha (TNF-α) gene are associated with both OCD and rheumatic fever, which is an Interesting finding because the TNF-α gene is a pro-inflammatory cytokine involved. In rheumatic fever and several other autoimmune diseases, suggesting that both obsessive-compulsive disorder and rheumatic fever share a common genetic vulnerability. [11]

PANDAS OCD can be a mild expression of rheumatic fever, which Is more common in developing countries, while the full development of rheumatic fever-related disorders may be reduced by appropriate antibiotic prophylaxis in developed countries. Consistent with this hypothesis, family history of rheumatic fever was higher In OCD PANDAS patients. Therefore, an abnormal immune response to this streptococcal infection, together with abnormal antibody production leading to basal ganglia damage, has been suggested as a possible mechanism for rheumatic fever and PANDAS OCD. This proposed mechanism Is supported by the behavioral changes and development of brain lesions in mice following immunization with streptococcal antigens, with similarities to similar studies investigating immune mechanisms in Sydenham's rats.

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Abnormal brain autoantibody production may itself be mediated by specific genetic factors, which may create an X gene environment (G x E) for a PANDAS subgroup. However, a puzzling anomaly that potentially reflects a different possible G x E interaction, or even confounds the importance of streptococcal infections and autoantibodies in OCD, Is that OCD patients with suspected PANDAS have an equal number of Relatives with OCD present in non-PANDAS comparisons. OCD Population Some recent reviews have concluded that the relationship between streptococcal infections and OCD may be Indirect and complex and thus "elusive," although other controlled studies continue to support an association. In addition to streptococcal and panda infections, there are other interesting examples of overt OCD development associated with infection. Both bacterial and viral infections are associated with acute-onset OCD, including Mycoplasma pneumoniae, varicella, toxoplasmosis, Berna disease virus, Behçet syndrome, and encephalitis, with some infections associated with striatal and other brain lesions. In some cases, specific OCD symptoms subsided with antibiotic treatment. [16]

 Onset of OCD and/or hoarding after acute traumatic brain injury and In association with other types of neuropathology

 A number of reports have described new-onset OCD in previously healthy individuals, usually with documented traumatic brain injury. In addition to OCD, other psychiatric disorders that develop following brain injuries have been documented in epidemiological studies.

In one such case, whichh retrospectively evaluated 5034 subjects, of whom 361 (8.5% weighted average) reported a history of concussion with loss of consciousness or confusion, the lifetime prevalence was It was significantly increased (P>0.03-0.0001) for many disorders, including OCD, compared to people without head injury. An odds ratio of 2.1 was reported for OCD, indicating a more than twofold increase in the occurrence of OCD compared with controls without head injury, after adjustments for age, gender, marital status, and socioeconomic status. Of note, although similar odds ratios were found for major depression and panic disorder, rates of schizophrenia or bipolar disorder were not Increased in this sample of concussed individuals. [18]

Some case series report acute onset of OCD within days to months after traumatic brain injury. One of the three studies recorded a set of OCD symptoms using the YBOCS rating. A subgroup of patients had the unusual symptoms of "obsessive slowness". Compared to a matched control group, patients with OCD symptoms had poorer performance on a range of cognitive measures, including executive functions, after brain injury. Also, patients with the most severe traumatic brain injury had frequent abnormal magnetic resonance imaging (MRI) examinations involving the frontotemporal cortex. Some of these reports specifically emphasized the absence of previous personal or family OCD symptoms or diagnoses.

 Smaller survey studies of post-traumatic brain injury patients with Ns of 100 or less and using a variety of diagnostic assessments have rarely reported cases of OCD, although OCD symptoms have been reported In other types of brain disorders. Surgery for seizure disorders and carbon dioxide poisoning, as well as brain tumors and stroke lesions affecting parts of the cortico-striato-pallidothalamic circuits. OCD and OC symptoms are also associated with other neurological disorders and neuropathologies found in Parkinson's disease, post-encephalopathic disorders, and other brain disorders. [15]

Acute new-onset OCD in patients with schizophrenia during treatment with atypical antipsychotics

 A recently recognized OCD-related disorder is atypical neuroleptic-related OCD, as reported in schizophrenic patients successfully treated with clozapine, ritanserin, and other newer neuroleptic agents. Some have suggested that this syndrome represents OCD-like symptoms induced by atypical neuroleptics—that is, a drug side effect. Others agree with the hypothesis that suppression of overt and dominant psychotic symptoms by clozapine and other atypical neuroleptics reveals OCD and makes the diagnosis possible. The latter is consistent with some previous studies suggesting that 5% to 20% or more of people with schizophrenia have OCD. It seems that more studies are needed to evaluate these two somewhat opposing views of this syndrome. [19]

Of note, other harmful life events of a psychological or social nature have been associated with different possible consequences for OCD. For example, one study compared patients with OCD plus post-traumatic stress disorder (PTSD) who developed OCD after clinically significant trauma (as "post-traumatic OCD") with general OCD patients In terms of characteristics. compared demographic and clinical data. Compared to general OCD patients, "post-traumatic OCD" showed several phenotypic differences such as: older age at onset of obsessions; increased rates of some obsessive-compulsive dimensions (such as aggressiveness and symmetry); increased maladaptive

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mood, anxiety, impulse control disorders and tics; "Suicide and severity of depressive and anxiety symptoms; and greater family history of PTSD, major depressive disorder, and generalized anxiety disorder." A study of a subgroup of treatment-resistant OCD found that all subjects meeting official criteria for OCD and PTSD had an onset of PTSD that preceded the onset of OCD. [15]

Possible chromosomal or genomic disorders associated with OCD

At present, studies on the possible genetic contribution to OCD and OCSD are very limited. Apart from research on specific genes and generated syndromes, as mentioned below, most efforts in the last decade have been directed towards genome-wide linkage and more recently genome-wide association studies, mainly based on cohorts of individuals with DSM. . -IV- OCD was diagnosed without concern for subtypes related to OCD. As reviewed previously and in this Issue, there have been several recent assessments of genetic contributions to OCD. In addition, specific investigations of some genes have been subjected to meta-analysis with positive results. [16]

Evaluation of OCD treatment responses

Like OCD, many OCD-related spectrum disorders respond to serotonin reuptake inhibitors (SRIs), whichh some use as evidence for a link between these conditions. However, given that people with these disorders often suffer from disorders that also respond to SRIs (such as major depressive disorder and other anxiety disorders), and also given the fact that many neurological and Other doctors who have no supposed connection to OCD also respond. For SRI therapy, this response to therapy seems clearly a weak hypothesis. On the other hand, it is noteworthy that many anxiety disorders, but not OCD, benefit from monotherapy with other types of anxiolytics such as benzodiazepines. [16]

Psychological treatments specific to OCD provide a more discriminating test for grouping disorders together based on treatment response. Ritual exposure and prevention (ERP) is one of the treatments of choice for OCD, and several studies have shown that body dysmorphic disorder and hypochondriasis also respond to psychological treatments containing ERP elements. Worth further study is a comparative examination of whether non-response to other antidepressants compared to anxiolytics such as benzodiazepines may characterize subtypes of these other OCD-related disorders. Data on such approaches are sparse, with very few head-to-head studies such as those In OCD of SRIs versus norepinephrine transporter inhibitors such as desipramine or drugs that affect other neurotransmitter systems. [17]

Brain imaging research of OCD patients has recently expanded to include some subtypes such as body dysmorphic disorder and compulsive hoarding. Specific investigations include positron emission tomography (PET) studies of glucose utilization and MRI-based volumetric studies of components of the cortico-striato-pallido-thalamic circuits most implicated In OCD. Another approach has been PET studies using specific ligands and studies based on magnetic resonance spectroscopy of specific brain chemicals to evaluate receptor and transporter elements of neurotransmitter signaling pathways .

Most studies so far have attempted to compare OCD patients with controls, or occasionally other groups of neuropsychiatric patients, or pre- and post-treatment comparisons. Obsessive compulsive disorder (OCD) has not been well researched. Cost, difficulty, and time limit the number of subjects that can be studied, and thus there are only very few studies of OCD subtypes, such as studies comparing OCD patients with and without hoarding and studies comparing OCD symptom dimensions. A similar situation exists for psychological and physiological measurements or endophenotypes and for animal models, all of whichh are in the process of searching for relevant measures of OCD phenotypes. [18]

conclusion

With recent advances In ongoing clinical and other research, the condition of OCD and OCD-related spectrum disorders is rapidly evolving, with many interesting new developments, and it Is hoped that this work will lead to a diagnostic scheme based on on the etiology, whichh in turn helps to advance the diagnosis and treatment of these debilitating diseases. The research results Indicate that OCD has two Important and sometimes independent elements: obsession and compulsion.

Obsession is an unwanted and frequent thought, mental image, or desire that a person finds uncomfortable and uncontrollable. Obsessive thoughts often take the form of harming or hurting yourself or someone important In your life. Obsessive-compulsive disorder, like other mental illnesses, is the result of a combination of different biological

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factors (genetic, psychological and social). However, different people with different signs and symptoms can have different combinations of factors, and this makes knowing and determining the cause of the disease very complicated. In general, the causative factors of this disorder Include biological factors, behavioral factors, psycho-social factors.

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Comparison of BKFO Test Scores for Core Stability and Muscle Endurance in Active Women Aged 18–25 with Chronic Groin Pain and Healthy Women in Urmia

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Abstract

This study aimed to compare BKFO test scores as a screening tool for assessing core stability and muscle endurance in active women aged 18–25 with chronic groin pain and a healthy group in Urmia. This cross-sectional analytical study included 34 participants (17 with groin pain and 17 healthy), selected through purposive sampling. The BKFO test was used to evaluate lumbopelvic stability, and demographic data were collected via questionnaires and physical examinations. Statistical analysis, including the Shapiro-Wilk test and independent t-test, revealed a significant difference in BKFO test scores between the two groups ($p < 0.05$), with the groin pain group showing poorer stability. The findings suggest that reduced core stability and muscle endurance may be risk factors for chronic groin pain. These results emphasize the importance of targeted rehabilitation and preventive measures to improve lumbopelvic stability in athletes.

Keywords: Core stability, groin pain, BKFO test, lumbopelvic stability, functional screening, athletes

Introduction

Groin and hip pain is a common musculoskeletal complaint among young and middle-aged individuals, significantly affecting their physical performance. Groin injuries are prevalent in multi-directional sports requiring activities such as running, jumping, repeated starts, kicking, shooting, speed, and twisting movements, including soccer, Australian football, rugby, cricket, ice hockey, basketball, and handball (Holmich et al., 2014; Thorborg et al., 2018). Recent studies have focused on injuries from proximal to distal regions. Given the interconnected chain of body segments, athletes require strength and stability in the trunk and lower limb muscles to maintain movement stability across all three planes (Leetun et al., 2004). Research indicates that joint instability and uncontrolled joint movements may alter lower limb and distal segment motion, increasing the risk of lower limb injuries (Ferber et al., 2015; Hein et al., 2012).

Functional tests have gained attention for identifying and correcting faulty movement patterns and preventing sports-related injuries caused by these patterns. Consequently, movement screening tests have expanded significantly to assess athletes' and active individuals' performance, identify movement pattern weaknesses, and predict injuries. Screening tests evaluate injury risk, functional movement deficits, neuromuscular control, balance, and core stability (Garrison et al., 2015; Kiesel et al., 2014). The goal of functional screening tests is to identify individuals at risk of injury, enabling appropriate interventions to correct movement impairments and improve physical readiness. Assessing core stability is essential for identifying motor control deficits and movement strategies. Given the close relationship between neuromuscular performance of the hip/groin muscles and the lumbopelvic complex, and their impact on movement patterns, and considering the lack of studies on screening tests for core stability and muscle endurance in women with hip/groin pain, this study aimed to compare BKFO test scores in active women aged 18–25 with chronic groin pain and healthy counterparts in Urmia.

Impact of Muscle Activity Impairment on Movement Patterns

Repetitive movements and prolonged improper postural alignment alter muscle tissue characteristics, leading to imbalances in the global muscle system. This causes stress and strain in specific directions on various body structures, which, if exceeding tissue tolerance, results in recurrent pain and chronic musculoskeletal pain syndromes.

Movement pattern disorders are a significant factor in musculoskeletal impairments. Therefore, efforts focus on achieving coordinated activity among all muscles within a balanced muscle system for pain treatment and prevention. Reduced or excessive activity in synergistic muscles involved in movement disrupts movement rhythm and causes pain. Thus, muscle activity levels or the sequence and timing of muscle activation are used as criteria for evaluating movement patterns.

Impact of Injury on Movement

Examining the effect of a localized distal joint injury on proximal muscle performance is critical in assessing and treating musculoskeletal injuries. Although few studies exist in this area, analyzing empirical evidence provides valuable insights into compensatory mechanisms. A controlled study by Cook et al. (2010) compared hip muscle performance in individuals with a history of severe unilateral ankle sprains to a control group. Electromyography recorded the activation patterns of the gluteus maximus, hamstrings, and lateral spinal extensors on both the affected and unaffected sides during prone hip extension. Analysis showed significant differences in muscle activation patterns in the injury group compared to the control group, observed on both sides. A notable difference was the delayed onset of gluteus maximus activation in the injury group. These subtle changes in muscle performance post-injury highlight the importance of comprehensive injury assessment.

Proximal changes may represent an inhibitory protective response to prevent further injury or may reduce or alter proprioception in the injured distal region, leading to decreased coordination in the proximal muscle system during functional activities. Alternatively, changes may stem from pain associated with the original injury, leaving a residual inhibitory effect even after the injury resolves.

These explanations align with findings by Vladimir Janda et al. (2017), who provided a framework for comprehensive rehabilitation addressing secondary proximal effects of primary distal injuries. The primary goal of movement screening is to assess fundamental movement patterns and motor control, identify restrictions or asymmetries, and evaluate their effects. Once significant asymmetries and restrictions are identified, more precise measurements can be conducted. The core idea of screening is to describe movement pattern quality using a simple grading system.

Research indicates a close anatomical and muscular relationship between the groin and lumbopelvic regions, influencing each other's performance. Studies show that athletes with groin pain exhibit core region deficits and musculoskeletal coordination issues compared to healthy peers. Given the lack of studies on female athletes engaged in activities prone to groin injuries, this study aimed to address this gap by comparing BKFO test scores for core stability and muscle endurance in active women aged 18–25 with chronic groin pain and healthy women in Urmia.

Study Design and Population

This cross-sectional analytical study included active women aged 18–25 engaged in multi-directional sports. The sample consisted of 34 active women (scoring 13–15 on the Baecke Physical Activity Questionnaire) in Urmia's futsal clubs, divided into healthy and groin pain groups. After coordination with Takhti Sports Complex in Urmia, participants meeting inclusion criteria completed information forms and were enrolled. The study was conducted over nine months in 2021–2022.

Sampling Method and Sample Size

Purposive sampling was used, with participants selected after completing consent forms, information questionnaires, and meeting inclusion/exclusion criteria. The sample size was calculated using G*Power software, with a statistical power of 0.80, a significance level of 0.05, and an effect size of 0.80, accounting for a 5% dropout rate, resulting in a total of 34 participants.

Inclusion and Exclusion Criteria

Inclusion Criteria for Women with Hip/Groin Pain:

- Groin pain during or after sports activity persisting for over six weeks

- Tenderness on palpation of the adductor tendon or pubic symphysis

- Positive squeeze test at 45° hip flexion or pain during active abduction against resistance

- No history of surgery in the lower abdomen, hip, or groin

- No inguinal hernia

- No history of low back or sacroiliac pain in the past year

- No neurological symptoms (e.g., numbness, burning, tingling) in the lower limbs

Inclusion Criteria for Healthy Individuals:

- Negative squeeze test at 45° hip flexion

- No history of lower limb injury in the past year

Ethical Considerations

This non-invasive study posed no risk to participants. All procedures were explained, and written information was provided. Participants signed informed consent forms and could withdraw at any stage. Data were protected and accessible only to the research team. The researcher facilitated participants' involvement in the study.

Research Tools and Data Collection

- Interview and Questionnaire: To assess healthy active women and those with hip/groin pain history

- Baecke Physical Activity Questionnaire: To determine physical activity levels

- Physical Examination: Conducted by a physiotherapist

- Consent Form: To confirm participants' willingness to participate

- Demographic Information Form: For individual data collection

- SECA 755 Analog Scale: For weight measurement (accuracy: 0.01 kg)

- SECA 220 Height Meter: For height measurement (accuracy: 1 cm)

- Omax Digital Timer: For recording test performance time (accuracy: 0.01 seconds)

- Pressure Device: To assess lumbopelvic stability during the BKFO test

Tests Used

Bent Knee Fall Out (BKFO) Test:

Participants lay supine, with a pressure device placed vertically under the lumbar spine, its lower edge 2 cm from the posterior superior iliac spine on the tested side. A rolled towel was placed under the lumbar spine where the leg rested flat on the ground. Participants flexed the knee on the tested side to 120° and slowly abducted and laterally rotated the hip to approximately 45°, then returned to the starting position. The other knee remained neutral, with the foot flat on the ground.

Procedure

Participants were active women aged 18–25 with or without groin pain, engaged in multi-directional futsal in Urmia's clubs. After coordination with club management and coaches, eligible participants were selected purposively based on inclusion/exclusion criteria and informed consent. A physiotherapist evaluated participants for groin pain, diagnosed by tenderness in the proximal adductor muscles and positive results in at least two specific tests (resisted adduction and squeeze test). Pain during the squeeze test was measured using a pain ruler. Each participant performed the screening test under identical conditions in a single session, with scores recorded. Data were compared between healthy and groin pain groups. For the groin pain group, core stability tests were conducted after inflammation subsided, as acute inflammation could affect performance.

Data Analysis and Hypothesis Testing

Descriptive statistics were used to extract participant characteristics, including central tendency and dispersion for age, height, weight, and BMI, presented in Table 1.

Table 1: Mean and Standard Deviation of Participants' Demographic Characteristics in Healthy and Groin Pain Groups

Group \ Variable	Healthy Group (Mean ± SD)	Groin Pain Group (Mean ± SD)	Significance (p-value)
Age (years)	21.82 ± 2.12	21.47 ± 2.29	0.66
Height (cm)	166.5 ± 4.57	167.9 ± 4.81	0.58
Weight (kg)	57.6 ± 4.67	58.5 ± 4.72	0.82
Body Mass Index (kg/m²)	20.3 ± 0.99	20.6 ± 1.02	0.40

Findings showed no significant differences in demographic characteristics between groups ($p > 0.05$). The Shapiro-Wilk test assessed data normality, and statistical analyses were performed using SPSS version 23, with a significance level of $p < 0.05$.

Table 2: Shapiro-Wilk Test Results for Study Variables by Group

Group	Variable	N	Significance (p-value)
Healthy Group	BKFO	17	0.55
Groin Pain Group	BKFO	17	0.61

The Shapiro-Wilk test showed that study variables were normally distributed in both groups ($p > 0.05$), allowing the use of the independent t-test to compare scores between groups.

The hypothesis stated a significant difference in lumbopelvic stability test scores between active women aged 18–25 with chronic groin pain and healthy counterparts.

Table 3: Mean Scores of Lumbopelvic Stability Between Healthy and Groin Pain Groups

Variable	Group	Mean ± SD	t value	Significance (p-value)
BKFO	Healthy	2.56 ± 0.90	-15.47	0.00
	Groin pain	10.48 ± 1.90		

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The independent t-test showed a significant difference in BKFO test scores for lumbopelvic stability between groups ($p < 0.05$). The groin pain group exhibited weaker stability and lumbopelvic dysfunction compared to the healthy group, confirming the hypothesis.

Conclusion

The BKFO test compared core stability performance between active women with chronic groin pain and healthy counterparts. Scores for core stability and muscle endurance were significantly lower in the groin pain group. Although it is unclear whether these results predate or result from the injury, the significant performance difference suggests these factors as key risk factors for groin injury recurrence. Thus, strengthening and enhancing core stability should be prioritized in managing this condition. Preventive programs focusing on screening and reducing injury risk factors are crucial. Reduced core stability and muscle endurance are significant risk factors, and rehabilitation targeting these areas is effective for prevention and treatment. It is recommended to focus on movement patterns, core stability, and muscle strength/endurance in rehabilitation and pre-season injury screening.

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The Effect of Whey Protein Supplementation on Urinary Protein Excretion Following an Exhaustive Resistance Training Session

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ABSTRACT

Proteinuria is a condition in which protein is excreted through urine, potentially indicating significant kidney damage. The aim of the present study was to investigate the effect of whey protein supplementation on proteinuria following a single session of exhaustive resistance training. Twenty-seven bodybuilding athletes were randomly selected and divided into two groups: a training group with supplementation (SUPP, n=14) and a non-supplemented training group (Non-SUPP, n=13). The exhaustive resistance training protocol consisted of five station-based exercises performed at 80% of one-repetition maximum (1RM). Urine samples were collected at four time points: before exercise, immediately after, one hour post-exercise, and 24 hours post-exercise. The urinary protein-to-creatinine ratio (UPCR) was used to assess proteinuria, and data analysis was conducted using the Mann-Whitney U test and Friedman ranking test. The mean age, height, weight, and body mass index (BMI) of the participants were 28.77 ± 7.82 years, 161.22 ± 6.02 cm, 56.44 ± 10.84 kg, and 21.59 ± 3.09, respectively. The mean UPCR of the Non-SUPP showed no significant difference compared to the SUPP ($p > 0.05$). Additionally, no significant differences were observed in the level of proteinuria among participants across the four measurement stages ($p > 0.05$). The findings of this study suggest that supplementation does not influence the level of proteinuria, consistent with previous research indicating that exercise-induced proteinuria is transient.

Keywords: Proteinuria, strength training, protein supplement.

INTRODUCTION

The optimal functioning of the kidneys, as a key component of the urinary system, is crucial for metabolic activities, particularly during physical exercise. This system aids in maintaining fluid concentration and homeostatic balance of acids and bases by excreting cellular waste products through urine. These mechanisms become even more critical during exercise. Any disruption in these processes can lead to complications that may adversely affect the optimal performance of physical activities. One such significant disorder is proteinuria, or the presence of protein in urine [1]. Proteinuria refers to a condition where protein is excreted through urine, which may represent a benign finding or indicate a notable renal or systemic disease [2]. In healthy individuals, urinary protein excretion is typically less than 150 milligrams per day [3]. Exercise-induced proteinuria is a common consequence following physical activity, with its prevalence varying between 18% and 100%, depending on the type and intensity of the exercise performed [4].

The urinary protein-to-creatinine ratio (UPCR) is a rapid and straightforward method for the quantitative assessment of urinary protein excretion. It is calculated by dividing the concentration of protein by the concentration of creatinine in a spot urine sample. This test has been reported to have high reliability and demonstrates a strong correlation with the 24-hour urine protein collection test, which is considered the gold standard [5]. A ratio exceeding 0.2 is regarded as indicative of varying degrees of proteinuria [6].

According to Poortmans, one of the pioneers in this field of study, the level of proteinuria varies depending on the type of exercise performed and is more prevalent in high-intensity activities. He has stated that the intensity of an

activity has a greater impact on the increase in proteinuria than its duration [7]. Following these studies, Carroll and Temte (2000) demonstrated that proteinuria is a common phenomenon in adults during exercise and is caused by intense physical training or strenuous exercise [8]. Atashghahian et al. (2014) reported that proteinuria is associated with exercise intensity [9]. There is a consensus that post-exercise proteinuria is transient in nature; however, it has been reported that excessive protein excretion in urine by the kidneys can lead to kidney dysfunction and the development of chronic kidney diseases [10].

Several studies have demonstrated a correlation between high protein intake and increased proteinuria as an early indicator of kidney damage. Additionally, multiple studies have reported an elevated risk of protein excretion associated with high dietary protein consumption compared to standard dietary protein intake in certain conditions, such as diabetes [11] or hypertension [12] [13–16]. However, based on the researcher's review, no studies have reported an association between the consumption of protein supplements and proteinuria in the general, healthy, or athletic populations.

The use of protein supplements is common among athletes. Ordinary individuals require 0.8 grams of protein per kilogram of body weight daily to meet their needs [17]. Certain conditions, such as exercise, alter daily requirements, with estimates suggesting that athletes participating in intense training may need 1.6 to 1.8 grams of protein per kilogram of body weight per day [18]. Most athletes who follow a regular diet meet this requirement without the need for protein supplements; however, many athletes consume higher amounts of protein to achieve personal and training goals, sometimes exceeding 2 grams per kilogram of body weight per day [19]. High protein intake can alter glomerular filtration in the kidneys, leading to concerns that excessive protein consumption by athletes may cause kidney damage [20].

According to Turgut et al. (2003), the concentration of urinary protein and creatinine increased in both boys and girls after two hours of volleyball training [21]. De Palo et al. (2002), in their study of cyclists [22], and Kocer et al. (2008), in their examination of mice using an aerobic exhaustion protocol (treadmill running) [23], reported that urinary protein excretion increased following a single training session. On the other hand, Etebari asl et al. (2017) found that a single session of intense aerobic exercise did not significantly affect the level of proteinuria [24]. The findings of Kohanpour et al. (2012) demonstrated that total protein and albumin levels in urine increased 20 minutes after a karate competition among young male athletes [25]. Lima et al. (2016) reported that the level of proteinuria before and after vitamin D supplementation was similar in adolescents with systemic lupus erythematosus [26]. These conflicting results from past studies, along with the lack of research investigating the impact of protein supplements on proteinuria, highlight the need for further research in this area.

The 2012 guidelines for chronic kidney disease explicitly identify proteinuria as one of the markers for staging the condition. Moreover, the level of proteinuria serves as an important predictor of disease progression, closely associated with the incidence of cardiovascular disease. Additionally, some studies have demonstrated that proteinuria can be utilized as a therapeutic target or endpoint in clinical treatment and prevention of cardiovascular complications, particularly for patients with high levels of proteinuria [27]. These associations, considering the growing tendency among athletes in various sports disciplines—especially bodybuilding—to consume protein supplements, underscore the importance and necessity of further research in this area.

Based on the researcher's review, no study has yet investigated the effect of whey protein supplements on urinary protein excretion. Therefore, given that whey protein supplementation is highly recommended in bodybuilding for various purposes, the following question arises: Does the consumption of these supplements affect the level of urinary protein excretion? Is there a difference in proteinuria between individuals who consume protein supplements and those who train without supplementation? In the present study, the effect of whey protein supplementation on urinary protein excretion was examined at four time points following an exhaustive resistance training session.

METHODOLOGY

The present study is a quasi-experimental, applied research design conducted using a pre-test and post-test model with a control group. The statistical population of the study consisted of all bodybuilding athletes from active clubs in Bandar Abbas, who were invited to participate through a public announcement among bodybuilding coaches via virtual platforms. From among the respondents, 27 individuals were randomly selected and divided into two groups: a group undergoing training with whey protein supplementation (SUPP, n=14) and a group undergoing training without whey protein supplementation (Non-SUPP, n=13). Participants were selected from volunteers based on inclusion criteria, which included the absence of kidney disorders, no food allergies. Written informed consent was obtained from all male bodybuilders interested in participating in the study, and a general data form, including demographic characteristics such as height, weight, and age, was completed for each participant. Participants were excluded from the study if they sustained injuries during training, engaged in physical exercises outside the prescribed

training program, or if their urine samples were not validated by the laboratory. This research was approved under the ethical code IR.IAU.YAZD.REC.1402.030 by the Islamic Azad University, Yazd Branch.

2.1 Exhaustive Resistance Training Protocol

Three days prior to the commencement of the training sessions, participants attended a pre-test session to determine their one-repetition maximum (1RM) for adjusting the weights during the main training session. Separate orientation sessions were held for two groups. The Brzycki formula was used to calculate the 1RM [28]. The training session consisted of general warm-up (10 minutes), specific warm-up (5 minutes), main training (40 to 45 minutes), and cool-down (5 minutes). The main training included five station-based weight training. The stations, in order, were as follows: front lat pulldown, leg extension, seated row, leg curl, and chest fly. Sets at each station were performed at 80% of the participant's calculated 1RM from the pre-test session until reaching exhaustion. A two-minute rest period was allowed between each station [29]. The training environment was identical for both groups, and all sessions were conducted between 8:00 AM and 11:00 AM.

To control for the effects of physical activity, participants were instructed not to engage in any exercise activities within 48 hours prior to the training session. Additionally, participants were asked to refrain from consuming any protein or non-protein supplements, as well as caffeine-containing foods and beverages—including tea, herbal teas, Nescafé, coffee, and energy drinks—within 24 hours before the training session.

2.2 Whey Protein Supplement

For the supplement-consuming (SUPP) group, whey protein was prepared at a dosage of 0.25 grams per kilogram of body weight and provided as a single serving on the day before the training session [19]. The supplement was consumed two hours prior to the training session by the participants with an ample amount of water. The whey protein used in this study was an Iranian product manufactured by Iliya Pars Food Industries, approved by the Ministry of Health, and purchased from a licensed pharmacy. To control for the effects of dehydration on urine samples, participants were instructed to drink water as much as possible within two hours before the training session.

2.3 Urine Sampling

To evaluate proteinuria in the participants, urine samples were collected at four time points: before exercise, immediately after exercise, one hour after exercise, and 24 hours after exercise. The demographic information of the participants was delivered to the laboratory, and after systematic registration, coded and labeled urine collection containers were received from the laboratory technician. Standardized and sterile containers were used for urine sample collection. The first, second, and third urine sampling were collected at the training site, while the 24-hour post-exercise sampling was collected at the participants' homes. To minimize variations in the protein-to-creatinine ratio and ensure more accurate results, the first and fourth sampling were collected at the same time of day. The urinary protein-to-creatinine ratio (UPCR) was used as the indicator for assessing proteinuria.

2.4 Statistical Methods

Data were analyzed using SPSS version 26. Mann-Whitney U test was used to compare the two groups, and the Friedman test was employed to assess differences across time points. The significance level for all statistical analyses was set at $P < 0.05$.

RESULTS

The mean age, height, weight, and body mass index (BMI) of the participants in the study were 28.77 ± 7.82 years, 161.22 ± 6.02 cm, 56.44 ± 10.84 kg, and 21.59 ± 3.09, respectively. The mean and standard deviation of UPCR for the participants at the four measurement time points are presented in Table 1.

Table 1. Description of UPCR at Sampling Stages

Groups	Time	Mean	Std. Deviation
Non-SUPP (n=13)	Before Training	0.11	0.14
	Immediately After	0.06	0.06
	1 hour After	0.13	0.23
	24 hours After	0.05	0.04
SUPP (n=14)	Before Training	0.04	0.02
	Immediately After	0.06	0.04
	1 hour After	0.06	0.07
	24 hours After	0.04	0.04

The mean UPCR of the SUPP group was lower at all measurement stages compared to the Non-SUPP group. (Figure 1).
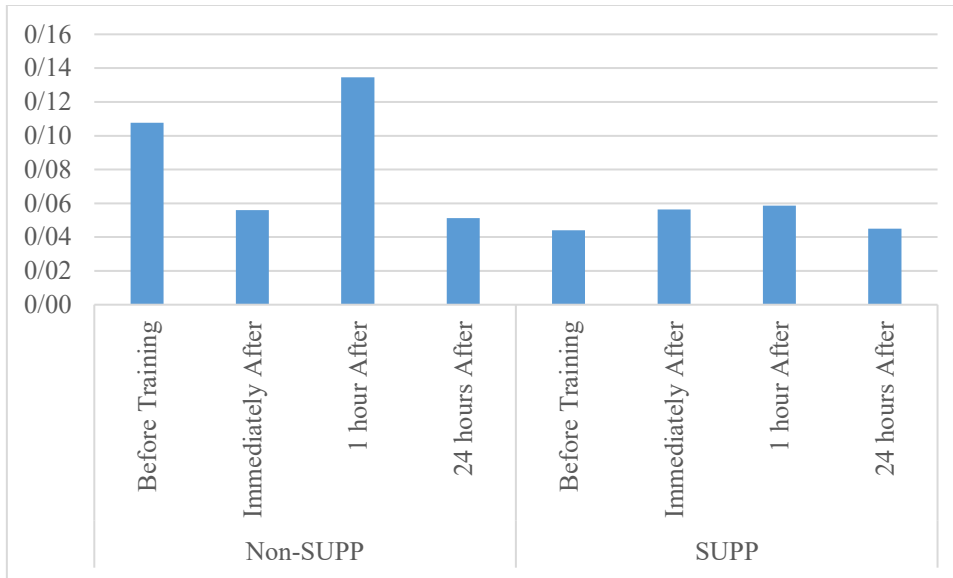
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Figure 1. Description of UPCR values for the two groups at different stages of the study.

Despite the increase in UPCR in the Non-SUPP group one hour after exercise, this increase was not significantly different compared to the SUPP group ($p > 0.05$) (Table 2).

Table 2. Results of the Mann-Whitney U Test for UPCR in the Two Groups

Time	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Sig
Immediately After	Non-SUPP	13	12.77	166.00	75.000	-0.777	0.437
	SUPP	14	15.14	212.00			
1 hour After	Non-SUPP	13	15.31	199.00	74.000	-0.825	0.409
	SUPP	14	12.79	179.00			
24 hours After	Non-SUPP	13	15.15	197.00	76.000	-0.729	0.466
	SUPP	14	12.93	181.00			

The Friedman ranking test indicated that there was no significant difference in the level of proteinuria among the participating athletes at the four measurement time points ($p > 0.05$) (Table 3).

Table 3. Friedman Test Analysis for UPCR at Sampling Stages.

Groups	Time	Mean± Std	Mean Rank	Chi-Square	df	Sig
Non-SUPP (n=13)	Before Training	0.11±0.14	3.15	4.77	3.00	0.19
	Immediately After	0.06±0.06	2.27			
	1 hour After	0.13±0.23	2.42			
	24 hours After	0.05±0.04	2.15			
SUPP (n=14)	Before Training	0.04±0.02	2.46	1.79	3.00	0.62
	Immediately After	0.06±0.04	2.75			
	1 hour After	0.06±0.07	2.64			
	24 hours After	0.04±0.04	2.14			

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DISCUSSION

The results of the present study indicated that whey protein supplementation had no effect on the level of proteinuria following a single session of resistance training. Additionally, it was observed that the mean UPCR in the SUPP group was consistently lower at all measurement stages. These findings suggest that whey protein supplementation does not influence the occurrence of exercise-induced proteinuria but may potentially play a role in enhancing the reabsorption of protein and creatinine from urine. No study was found in the research literature where variables similar to those tested in the present study were examined under comparable hypotheses. Assis et al. (2020) investigated the effect of 1.8 grams of whey protein per kilogram of body weight after swimming exercise at an intensity of approximately 50% and observed a significant increase in serum creatinine levels in laboratory mice post-exercise [30]. In the study by Mansuri and Moorjani (2019), daily dietary protein intake was collected via a questionnaire, and no supplements were prescribed; these researchers reported a significant association between urinary creatinine excretion and dietary protein intake [31]. In the present study, we measured UPCR before and after a single resistance training session in 27 bodybuilding athletes, 14 of whom consumed whey protein supplementation (0.25 grams of whey protein per kilogram of body weight) alongside their training regimen. These differences in research methodology justify the variations in the findings.

The prevailing hypothesis regarding the causes of post-exercise proteinuria suggests that this condition arises from two processes: increased permeability of glomerular filtration and reduced reabsorption by renal tubules. Disruption in these two mechanisms leads to the leakage of proteins into the urinary space during periods of physical activity [32, 33]. In the present study, considering the distinct nature of the exercise (weight training), the selected training program (five compound stations), the supplement and prescribed dosage (an average of 0.25 g/kg weight), the studied participants (bodybuilding athletes), and ultimately the planned exercise intensity (80% of one-repetition maximum), resistance training combined with whey protein supplementation did not result in exercise-induced proteinuria. It is likely that this level of whey protein supplementation had no adverse effects on increasing glomerular filtration permeability or reducing tubular reabsorption. Whey protein is a high-quality protein source rich in essential amino acids with high bioavailability. Some studies have shown that whey protein may have beneficial effects on kidney health, such as reducing blood pressure [34], improving glucose metabolism, and modulating oxidative stress and inflammatory responses [35, 36]. Therefore, it is plausible that consuming whey protein supplements alongside exercise does not exacerbate exercise-induced proteinuria but instead optimizes it or has no significant impact on it.

The majority of studies in this field have focused on the effects of aerobic exercises on proteinuria. Further investigation is needed to determine both the acute and long-term effects of resistance training, as well as the impact of various supplements, which exhibit significant diversity and variability in bodybuilding and are increasingly consumed. The findings of the present study can serve as a foundation for such future research.

The effects of sports supplements on kidney function have been the subject of considerable research, yet the results remain inconsistent and inconclusive. A number of studies have investigated the potential relationship between physical exercise and urinary protein excretion, predominantly focusing on athletes engaged in aerobic activities across various protocols. In contrast, limited attention has been devoted to examining the impact of weight training on renal function. Furthermore, while some studies have incorporated blood biomarkers alongside urinary parameters in their analyses, these measures represent promising avenues for future research aimed at evaluating the effects of sports supplements on kidney health. This area of study warrants more extensive investigation to draw definitive conclusions.

One notable limitation of the present study is its relatively small sample size, which may necessitate caution when generalizing the findings to larger populations. As such, further research with larger and more diverse cohorts is essential to validate and expand upon the current understanding of how sports supplements influence kidney function. Future investigations should also aim to address gaps in the literature, particularly concerning the role of weight training exercises and the utility of combined biomarker assessments in this context.

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Mental health and ways to achieve it from the perspective of Nahj al-Balagha

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Abstract:

Mental health, as one of the fundamental pillars of a healthy and successful life, has garnered special attention in various societies. *Nahj al-Balagha*, a book of speeches and letters by Imam Ali (AS), addresses topics such as ethics, social behavior, mental health, self-awareness, patience, piety, faith in God, and self-reformation .In today's world, with increasing social and economic pressures, the importance of mental health is more evident than ever. This research aims to introduce a spiritual and ethical model to achieve mental health. The article explores ways to attain mental well-being from the perspective of *Nahj al-Balagha* and its connection to educational psychology .Designed as a descriptive-analytical study, the research employs various methods for data collection and analysis. The findings demonstrate that *Nahj al-Balagha's* teachings serve as a rich and valuable source for improving mental health and enhancing the quality of individual and social life. Applying these teachings in daily life can help reduce psychological issues such as anxiety, depression, and mental fatigue. These teachings not only improve individual quality of life but also strengthen social bonds, increase community cohesion, and promote a culture of peace and tranquility at the global level .Given the profound impact of mental health on all aspects of human life, applying *Nahj al-Balagha's* teachings is recommended as a spiritual and ethical approach toward achieving a peaceful and healthy life. Research highlights that religion and spirituality play a crucial role in improving mental health.

Keywords: Mental Health, Nahj al-Balagha, Self-Awareness, Social Connections, Piety

Introduction

Mental health refers to a state of psychological and emotional well-being that affects the quality of life for individuals and is considered one of the fundamental pillars of human life. In today's world, with increasing social and economic pressures, the importance of mental health is more evident than ever. *Nahj al-Balagha*, as a rich source of ethical and social teachings, can be used as guidance for achieving mental health.

The purpose of this article is to explore strategies for achieving mental health from the perspective of *Nahj al-Balagha*. This article seeks to introduce and analyze the teachings of Imam Ali (AS) in various ethical and spiritual domains that can contribute to enhancing mental health in individual and social life. Additionally, the article aims to demonstrate how these teachings can be applied in today's modern and complex world to reduce psychological issues and achieve inner peace.

Ultimately, the objective of this research is to present a spiritual and ethical model for achieving mental health, inspired by the teachings of *Nahj al-Balagha*, which can positively impact the quality of individual and social life.

1-Research Background

Numerous studies have explored the relationship between mental health and spirituality, and their collective findings underscore the significance of this connection. For instance, Hosseini (2021) in an article titled "The Role of Spirituality in Mental Health," investigated the impact of spirituality on mental well-being. Additionally, Mousavi (2027) in their research, "A Look at Mental Health from a Religious Perspective," examined Islamic viewpoints on mental health and its associated solutions. These studies collectively highlight that religion and spirituality can serve as influential factors in enhancing mental health

2- Dimensions of Mental Health in Nahj-ul-Balagha

Self-Awareness and Self-Knowledge: Imam Ali (AS) emphasizes the importance of self-knowledge and understanding one's strengths and weaknesses. In a well-known saying, he states, "Man man ta'arafa, faqad ta'arafa rabbah".

Translated, it means, "Whoever knows himself has known his Lord".

Self-awareness enables individuals to better understand their emotions and thoughts, leading to improved mental health. By gaining insight into our own minds, we can foster a deeper understanding of our decisions and actions, ultimately contributing to a healthier mental state

The field of psychology offers valuable insights to help individuals understand themselves and their mental challenges better. Self-awareness is a crucial aspect of achieving psychological balance, and it is recognized as a fundamental principle in mental health.

In the realm of educational psychology, theories emphasize the significance of self-knowledge and understanding one's strengths and weaknesses. For instance, Carl Rogers, in his self-concept theory (1951), highlights the importance of self-awareness and its impact on mental well-being. By acknowledging and accepting our true selves, we can foster a healthier mental state and improve our overall quality of life.

Self-Actualization and Spiritual Practices

Additionally, Abraham Maslow's hierarchy of needs (1943) suggests that individuals must fulfill their basic needs to achieve self-awareness and self-acceptance. According to Maslow, once physiological and safety needs are met, individuals can ascend to higher levels of psychological development, including self-actualization.

In the context of Nahj-ul-Balagha, Imam Ali (AS) emphasizes the importance of piety (taqwa) as a foundational aspect of morality. In Sermon 881, he states, "Al-taqwa ra's al-khulq," meaning "Piety is the pinnacle of ethics." Practicing piety and avoiding sin contribute to a virtuous life, fostering inner peace and spiritual well-being.

Piety, Self-Control, and Mental Health

Piety, as emphasized in Nahj-ul-Balagha, cultivates self-discipline and helps individuals refrain from sinful acts. This concept aligns with the principles of educational psychology, which highlights the importance of self-control and managing inappropriate behaviors. Research in psychology supports the notion that piety and self-control are positively associated with improved mental health and reduced engagement in undesirable behaviors (Baumeister, 1995.(

Ryan and Deci (2000) further suggest that individuals who adhere to moral principles and practice piety are more likely to develop self-control and, consequently, experience enhanced mental well-being.

Piety as a Fortress

In Wisdom 820, Imam Ali (AS) states, "Al-taqwa hisn al-hasin," which translates to "Piety is an impenetrable fortress." This metaphorical expression conveys that piety safeguards individuals from the pitfalls of sin and immoral acts.

Leading a life guided by moral principles and avoiding undesirable behaviors contributes to a sense of inner peace and psychological well-being. By embracing piety, one can fortify their spiritual resilience and foster a healthier mental state.

Social Connection and Moral Society

Given that Islam is a socially oriented religion, emphasizing collective values and ideals, Imam Ali (AS) highlights the interdependence of societal well-being and moral conduct. In Wisdom 857, he states that the reform of a society is contingent upon the reform of its leaders and vice versa. When the governed fulfill their duties towards the government, and the government upholds the rights of its people, righteousness prevails.

This perspective underscores the importance of social connections and shared moral responsibilities in building a healthy and harmonious community, which, in turn, contributes to individual mental health and overall societal progress.

Social Dysfunction and Mental Health

Imam Ali (AS) warns that when the governed dominate their leaders or when leaders oppress their people, societal harmony is disrupted. This leads to the corruption of religious decrees and the abandonment of moral traditions,

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resulting in a society governed by whims and desires. Such a scenario breeds moral illnesses and contributes to individual and societal decline.

From a psychological perspective, positive social connections and a sense of belonging reduce stress and anxiety (Cohen & Wills, 1985). Therefore, the societal values emphasized in Nahj-ul-Balagha, when upheld, can foster mental well-being and a healthier community.

Patience and Resilience

Patience and endurance in the face of challenges and hardships are highly regarded in Nahj-ul-Balagha. In Wisdom .153, Imam Ali (AS) states, "Al-sabru miftah al-nasr," meaning "Patience is the key to victory".

This proverb encourages individuals to cultivate resilience and perseverance, recognizing that overcoming obstacles and achieving success often require a steadfast mindset. Such a virtue can significantly contribute to an individual's mental fortitude and overall well-being.

Patience and Mental Resilience

Patience, as encouraged in Nahj-ul-Balagha, enables individuals to maintain their composure and cope more effectively with life's challenges. It is recognized as a crucial skill in stress management and problem-solving, as highlighted in psychological research (Folkman & Lazarus, 1984)

Studies indicate that individuals with higher levels of patience tend to exhibit better mental health and adaptability in the face of adversity. This virtue fosters mental resilience, allowing people to navigate difficult situations with a calmer and more balanced mindset.

Faith and Psychological Well-being

Faith in God and reliance on Him are fundamental principles for attaining inner peace, as emphasized by Imam Ali (AS) in Sermon 25: "Man tawakkala 'ala Allah, kafah Allah".

Faith provides individuals with a sense of security and tranquility. The human soul, akin to a tree, thrives when rooted in a divine connection. Without this spiritual bond, it withers and becomes depressed. Prayer is the most intimate expression of this connection. By praying, individuals foster a deeper bond with God, finding solace and strength.

Belief in God equips individuals with the resilience to face life's challenges, offering a sense of purpose and

Belief in God equips individuals with the resilience to face life's challenges, offering a sense of purpose and comfort that significantly contributes to mental well-being.

Faith, Spirituality, and Mental Health

Educational psychology also emphasizes the significance of spirituality and connection with a higher power in enhancing mental health. Studies indicate that faith and spirituality provide individuals with reassurance and tranquility, strengthening their resilience in the face of life's challenges (Pargament, 1997).

Renowned French physician and psychologist Alexis Carrel, in his famous book *Prayer*, writes, "Prayer, while bringing peace, also creates a kind of expansion in human brain activity, sometimes stirring the spirit of courage and heroism. Unfortunately, in our world, very few recognize prayer in its true essence".

Imam Ali (AS), in Sermon 46, states, "Al-du'a mafaateeh al-najah wa muqalida al-falah," meaning "Prayer is the key to success and the means to prosperity." This highlights the transformative power of prayer in fostering mental well-being and spiritual growth.

Self-Reform and Moral Improvement

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Self-reform and striving for personal moral and behavioral improvement are essential pathways to mental well-being, as highlighted by Imam Ali (AS) in Wisdom 359: "Ya ayuhal-nasu, tawalaw min anfusikum ta'dibaha, wa a'dilu biha 'an dararaha 'adatihha".

This exhortation encourages individuals to discipline themselves and break free from harmful habits and behaviors. Educational psychology supports the notion that self-regulation and moral development are crucial aspects of fostering a healthy mind (Bandura, 1977). By cultivating positive behaviors and ethics, individuals can enhance their overall mental health and contribute to a more harmonious society.

Practical Strategies for Mental Well-being

Gratitude: Cultivating gratitude and appreciating God's blessings can significantly impact an individual's outlook on life, fostering a positive mindset and increased mental tranquility. Research supports the idea that gratitude enhances life satisfaction and improves mental health (Emmons & McCullough, 2003.(

Imam Ali (AS), in Wisdom 244, emphasizes the importance of gratitude, stating that acknowledging God's blessings leads

"When hardships reach their peak, relief will come. At that moment, the chain of trials tightens, and the time of comfort and ease arrives. Psychology also recognizes hope as one of the key factors in improving mental health and reducing depression. Studies indicate that hopeful individuals enjoy better mental health and are more resilient when facing life's challenges (Snyder, 1995)

Therefore, in an era like ours, instead of lamenting over painful events and terrible corruptions that have surrounded Muslims from all sides, we must actively take action. Against the enemy's advanced propaganda tools, we should utilize the most advanced media tools of the day, and in response to unhealthy centers, we must provide healthy recreational facilities for our youth (Makarem Shirazi, 2010, Vol. 1, p. 158)".

Life Satisfaction:

Life satisfaction and acceptance of current circumstances help individuals achieve greater psychological tranquility. Imam Ali (AS) says, "Among the people, the one who is at peace is the one who is content. Contentment is the joy of life." Psychological research indicates that life satisfaction and acceptance of current conditions lead to increased happiness and improved mental health (Diener et al., 2002.)

If life becomes meaningless for an individual, everything will appear dark and grim. Wealth and comfort are too insignificant to serve as the meaning of our lives. Discovering the meaning of life provides a sense of value and tranquility. Allport says: "Nowadays in Europe, psychologists and psychiatrists have clearly turned away from Freud, who attributed psychological distress to sexual frustration, and have embraced 'Existential Therapy,' with Logotherapy being one of its schools of thought." (Viktor Frankl, *Man's Search for Meaning*, p. 1)

Imam Ali (AS) also states: "If you do not achieve what you desire, pay no mind to your current state. Desire what has happened, and do not be upset with what is. If you do so, you will find both the strength to face difficulties and a peaceful life." (*Ghorar al-Hikam*, Tamim Amadi, Hadith 1545)

Resilience:

Resilience and the ability to cope with challenges and difficulties are among the key factors in achieving mental health. Imam Ali (AS), in wisdom 216, says: "In trials, be like a two-year-old camel that neither has a back to be ridden nor udders to be milked".

From a psychological perspective, resilience is considered one of the most important skills in managing stress and improving mental health. Studies indicate that individuals with greater resilience and the ability to cope with life's challenges enjoy better mental health (Masten, 1995).

In today's era, with the rise in psychological and social harm, resilience can help individuals withstand stressful and anxiety-provoking factors, protect them from the causes of many psychological issues, and also enhance the positive functions of their lives.

Research Type:

This article is written in a descriptive-analytical format and examines the teachings of *Nahj al-Balagha* and their relationship with recent psychological findings. The data used in this research include scholarly articles, books, and credible sources in the fields of psychology and religion. Additionally, existing statistics on mental health and the impact of spirituality on it have been utilized. This research seeks to identify and analyze the relationship between religious teachings and mental health in contemporary society.

The present study explores the connection between the teachings of *Nahj al-Balagha* and mental health. It is designed in a descriptive-analytical format and employs various methods to gather and analyze data. Details of the research method, statistical population, data collection techniques, and data analysis methods are explained further.

Research Type:

The present research is descriptive-analytical in nature. This type of research examines and analyzes concepts and theories, aiming to gain a deeper understanding of the connection between religious teachings and mental health. In this study, efforts are made to use available data and analyze it to achieve scientific and practical results.

Statistical Population:

The statistical population of this research includes individuals who are committed to the teachings of *Nahj al-Balagha* and religious principles, as well as those who actively participate in spiritual and religious activities.

Methods of Data Collection:

Various methods are employed for data collection, including:

1 .Library Research: Reviewing and analyzing credible texts and resources related to *Nahj al-Balagha* and mental health, which include scientific articles, books, and relevant theses.

2 .Questionnaires: Designing questionnaires to collect quantitative data from the statistical population. These questionnaires include questions related to mental health, spirituality, and adherence to religious teachings

Interviews:

Semi-structured interviews are conducted with individuals active in religious and psychological fields. These interviews help gather deeper and qualitative data.

1 .Methods of Data Analysis:

The collected data are analyzed both quantitatively and qualitatively.

 –**Quantitative Analysis** :

  Questionnaire data are analyzed using statistical software, such as SPSS or Excel. This includes calculating the mean, standard deviation, and conducting statistical tests such as t-tests and ANOVA to examine differences and correlations .

  The table above demonstrates that life satisfaction and improved mental health are directly linked to patience and resilience, as influenced by the teachings of *Nahj al-Balagha* and religious principles.

 –**Qualitative Analysis** :

  Interview data are analyzed through content analysis. This involves identifying patterns, themes, and key concepts in the responses of the interviewees.

2 .Validity and Reliability of the Research:

To enhance the validity and reliability of the research, the following methods are used:

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–**Standardized Questionnaires** :

Using reliable and standardized questionnaires in the fields of mental health and spirituality.

–**Pilot Testing** :

Conducting a pilot test on a small group from the statistical population to ensure the clarity and accuracy of the questions.

–**Expert Consultation** :

Consulting experts in the fields of psychology and religion to validate the content of the questionnaires and interviews.

:Presentation of Findings and Innovation of the Article

This study examines the relationship between the ethical and spiritual teachings of *Nahj al-Balagha* and mental health. The findings show that the teachings of *Nahj al-Balagha*, including an emphasis on patience, piety, self-awareness, and social connections, play a key role in improving mental health. These teachings not only help reduce anxiety, depression, and mental fatigue but also enhance life satisfaction and strengthen social relationships among individuals.

Innovation or Novelty of the Article:

1 Utilizing the teachings of *Nahj al-Balagha* to propose a spiritual and ethical model as an innovative approach in the modern world .

2 .Combining religious concepts with educational psychology to analyze the effects of spirituality on mental health .

3 .Employing precise statistical analyses to scientifically evaluate the effectiveness of these teachings.

Methods and Statistical Tests for Data Analysis:

–**Data Collection** :

Quantitative data were collected through standardized questionnaires. These questionnaires included questions on mental health, patience, resilience, and spirituality. Additionally, qualitative data were obtained through semi-structured interviews .

–**Quantitative Data Analysis** :

The questionnaire data were analyzed using SPSS software. The following statistical tests were employed for evaluation and analysis :

1 .Independent t-test: To examine the differences in means between groups (e.g., individuals adhering to spiritual teachings versus those who do not .(

2 .٢Analysis of Variance (ANOVA): To analyze the relationships between variables, such as life satisfaction and resilience .

3 .Pearson Correlation Coefficient: To assess the strength of the relationship between mental health and spirituality .

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–**Qualitative Data Analysis** :

  The responses obtained from interviews were analyzed using qualitative content analysis. Key patterns, themes, and concepts, such as the impact of *Nahj al-Balagha's* teachings on mental peace, were identified and categorized.

 –**Reliability and Validity** :

  To ensure the validity of the results, the questionnaires used were evaluated for reliability through Cronbach's alpha test, and pilot tests were conducted on smaller sample groups.

This combined approach of statistical methods and qualitative analysis has added depth and accuracy to the research findings, increasing their applicability.

Presentation of Findings and Innovation of the Article:

This research examines the relationship between the ethical and spiritual teachings of *Nahj al-Balagha* and mental health. The findings indicate that the teachings of *Nahj al-Balagha*, including an emphasis on patience, piety, self-awareness, and social connections, play a key role in improving mental health. These teachings not only help reduce anxiety, depression, and mental fatigue but also enhance life satisfaction and strengthen social relationships among individuals.

Innovation or Novelty of the Article:

1 .Utilizing the teachings of *Nahj al-Balagha* to propose a spiritual and ethical model as an innovative solution in the modern world.

2 .Integrating religious concepts with educational psychology to analyze the effects of spirituality on mental health.

3 .Employing precise statistical analyses to scientifically evaluate the effectiveness of these teachings.

Conclusion:

The present research method delves deeply and comprehensively into the connection between *Nahj al-Balagha* and mental health. By utilizing various methods of data collection and analysis, this study aims to provide scientific and practical results that can contribute to improving mental health in society.

The teachings of *Nahj al-Balagha* can serve as effective strategies for achieving mental health and improving the quality of individual and social life. By applying these teachings, one can achieve psychological balance and become mentally stronger. These teachings are not only significant from a religious perspective but are also valuable from an educational psychology standpoint.

Imam Ali (AS) emphasizes principles in *Nahj al-Balagha* such as self-knowledge, piety, patience, faith in God, hope, life satisfaction, social connections, and self-improvement. These teachings directly help alleviate anxiety, stress, and psychological crises, guiding individuals toward inner peace and mental stability.

Moreover, Imam Ali (AS) specifically highlights the importance of social relationships, piety, refraining from sin, and remembering God as factors influencing mental health, which remain applicable in modern times.

The results of this research indicate that incorporating the teachings of *Nahj al-Balagha* into daily life can reduce psychological issues such as anxiety, depression, and mental fatigue. These teachings not only enhance the quality of individual life but also serve as tools for strengthening social relationships, increasing cohesion in society, and

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promoting a culture of peace and tranquility on a global scale. Ultimately, given the significant impact of mental health on other aspects of human life, the use of *Nahj al-Balagha* teachings can be recommended as a spiritual and ethical approach toward achieving a healthy and peaceful life.

Limitations:

1. Lack of access to resources: In some regions, access to educational and counseling resources is limited.

2. Cultural resistance: Some individuals may refrain from consulting counselors and psychologists due to cultural beliefs.

3. Lack of awareness: A general lack of public awareness about the importance of mental health and its connection with religion and spirituality can hinder the acceptance of these valuable teachings.

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