

Original Article

Vitamin E and Selenium Facilitate the Osteogenesis and Adipogenesis of the Human Adipose Tissue-Derived Mesenchymal Stem/Stromal Cells

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ABSTRACT

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Background and Aims: Previous studies have shown that adipose-derived mesenchymal stem/ stromal cells are one of the sources of mesenchymal stem cells (MSCs) with the capacity to differentiate into various mesodermal cell lineages. MSCs with cytokines secretion capability, which contributes to repair damaged tissues have gained wide credence for future cell-based therapeutic applications. In this study, the effect of the different dosages of vitamin E and Selenium was assessed on the stemness of the human adipose tissue-derived MSCs (AD-MSCs).

Materials and Methods: Following 24 hours of cell treatments with different dosages of vitamin E and Selenium, MTT assay was used to assess the effect of them on cell proliferation. Moreover, the stemness of the AD-MSCs was assessed using osteogenic and adipogenic induction medium supplemented with the different dosages of the vitamin E and Selenium. Finally, Alizarin red and Oil-red O staining were performed to detect matrix mineralization and lipid droplet accumulation, respectively.

Results: MTT data revealed that the optimal concentration for vitamin E and Selenium were 125 μ M and 121 μ M for the viability of the AD-MSCs. Moreover, the effect of vitamin E and Selenium were assessed by osteogenic and adipogenic differentiation by optimal dosages obtained by MTT assay, respectively. Maximum mineralization and lipid droplet aggregation of the differentiated cells were detected at IC₅₀ in comparison with the control group.

Conclusions: These results suggest that different dosages of vitamin E and Selenium could have various impacts on the proliferation and differentiation induction of human AD-MSCs.

Introduction

Multipotent mesenchymal stem cells (MSCs) have the self-renewal capacity and also differentiation potential into various cell types of mesodermal cell lineages [1]. Human MSCs can be derived from different sources such as adult bone marrow, adipose tissue, umbilical cord, cord blood, amniotic membrane, amniotic fluid, human embryonic stem cells (hESCs) and other sources [2-4]. Among the different MSCs sources, adipose-derived MSCs (AD-MSCs) has led to more attention due to its high abundance, an available and accessible application as well as sustainability [5].

On the other hand, several reports have indicated that reactive oxygen species (ROS) can cause the inhibition of the MSC proliferation and immunomodulation, senescence promotion. Moreover, ROS can increase adipogenic differentiation while reducing osteogenic. Therefore, the effect of the mitochondrial metabolism onto the differentiation capacity of the human MSCs was assessed [6].

Mitochondrial electron transport systems are the main source of ROS which produce by nicotinamide adenine dinucleotide phosphate oxidases, xanthine oxidase, cytochrome P450, nitric oxide synthases, lipoxygenases, heme oxygenase, cyclooxygenases, myeloperoxidase, and monoamine oxidases [7]. Thereby, antioxidants can be used to protect the body against free radicals. The antioxidant system includes natural enzymatic and non-enzymatic factors that neutralize the harmful effects of oxidant [8]. Based on the chemical structure,

vitamin E can be used as an antioxidant in a group of potent, lipid-soluble, chain-breaking antioxidant, due to its lipid solubility, MSCs treatment with vitamin E protected against H₂O₂-induced apoptosis and promoted MSC survival via the AKT pathway and increase the proliferation and differentiation of MSCs [9-11]. In recent years, studies have shown the effect of vitamin E on the various stem cells such as embryonic stem cells, melanoma stem cells and mesenchymal stem cell have been investigated [12-15].

In addition, Selenium is known as an antioxidant and cofactor of many enzymes and the potential of Selenium to stimulate stem cell proliferation potency. For example, Selenium play a vital role in redox regulation in intracellular signaling via selenocysteine or Selenium-binding protein 1 (SELENBP1) is an indicator of cell differentiation/maturation adipocyte, and it can catalyze the oxidation of methanethiol [16-19]. Also, Selenium dioxide nanoparticles can improve the proliferation of ADSCs and bone marrow (BM-MSCs) [20]. Selenium can impact on normal myocardial differentiation and development by targeting miRNA [21].

Survival of MSCs, against oxidative stress is vital for stem cell therapy. Based on the AD-MSCs have shown potential for stem cell therapy owing to their antioxidant activity [13]. Due to the supportive effect of the antioxidants to induce proliferation and differentiation, this issue encouraged us to assess the best dosage of the vitamin E and

Selenium for proliferation and differentiation of the AD-MSCs. In this study, the antioxidant influence of the Vitamin E and Selenium was investigated on the proliferation and viability of the AD-MSCs was evaluated using methyl thiazolyl diphenyl-tetrazolium bromide (MTT) technique and their effect on the osteogenic and adipogenic differentiation of the AD-MSCs.

Materials and Methods

AD-MSCs cell culture

AD-MSCs were purchased from the Yazd Cardiovascular Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran (Ebrahimi *et al.*, unpublished data). The AD-MSCs were passaged using Trypsin/EDTA (Shellmax, China) and seeded into the tissue culture flask containing Dulbecco's modified eagle medium+20% fetal bovine serum (DMEM+20% FBS) (Shellmax, China) and incubated in the humidified atmosphere at 37°C and 5% CO₂ (Heracell 150i, Thermo scientific, American). Following cell attachment, the culture medium was changed every other day.

MTT assay

Cell viability was assessed using MTT assay according to the company instruction (Biomatik, Germany) Initially, 5×10³ cells/well were seeded into 96-well plates and incubated at 37°C, 5% CO₂ humidified atmosphere for 24 hr. Then the medium was aspirated, and cells were treated with 50, 100, 300, 500, 700, and 750 µm of vitamin E and Selenium solution. 24 hr later, 0.5 mg/mL MTT was added for IC₅₀ absorbance

Measurement at 570 nm using the enzyme-linked immunosorbent assay reader.

Osteogenic and adipogenic analysis using alizarin red and oil red staining

To investigate the effects of vitamin E (Sigma, Germany) and Selenium (Sigma, Germany) on osteogenic differentiation, the 5 × 10³ cells of AD-MSCs were cultured into each well of the 5-well plate by DMEM+20%FBS and incubated at 37°C, 5% CO₂ humidified atmosphere. At 80% confluency, the medium was replaced with osteogenic medium (Bonyakhte, Iran) and adipogenic medium (Bonyakhte, Iran) while treated with optimal (IC₅₀) dosages of vitamin E and Selenium compares with control group (osteogenic or adipogenic medium without of Selenium or vitamin E). The differentiation medium was changed every three days for 17 days. Finally, matrix mineralization and lipid droplet accumulation of the differentiated cells analyzed using Alizarin red (Bonyakhte, Iran) and Oil-red (Bonyakhte, Iran) staining, respectively. Tests were repeated three times in each group

Statistical analysis

Differences between groups were examined for statistical significance using a t-test with SPSS version 25. All data were representative of the mean±SD of the mean. The difference was considered to be significant for P<0.01.

Results

Effect of vitamin E and Selenium on AD-MSCs viability

In this study, successful isolation and proliferation of human AD-MSCs with

fibroblast-like morphology, was confirmed (Fig. 1 A, B). The antioxidant effect evaluation of vitamin E and Selenium on the viability of the AD-MSCs was assessed using MTT test. MTT data revealed a preferred concentration of vitamin E between 50 to 700 μM dosages, survival percentage of the cells reduced from

59.46% to 21.8%. IC50 was observed at 125 μM concentration of vitamin E ($p < 0.001$) (Fig. 2) and Selenium between 50 to 750 μM dosages, the survival percentage of the cells reduced from 61.4% to 22.6%. IC50 was observed at 121 μM concentration of Selenium ($p < 0.001$) (Fig. 3).

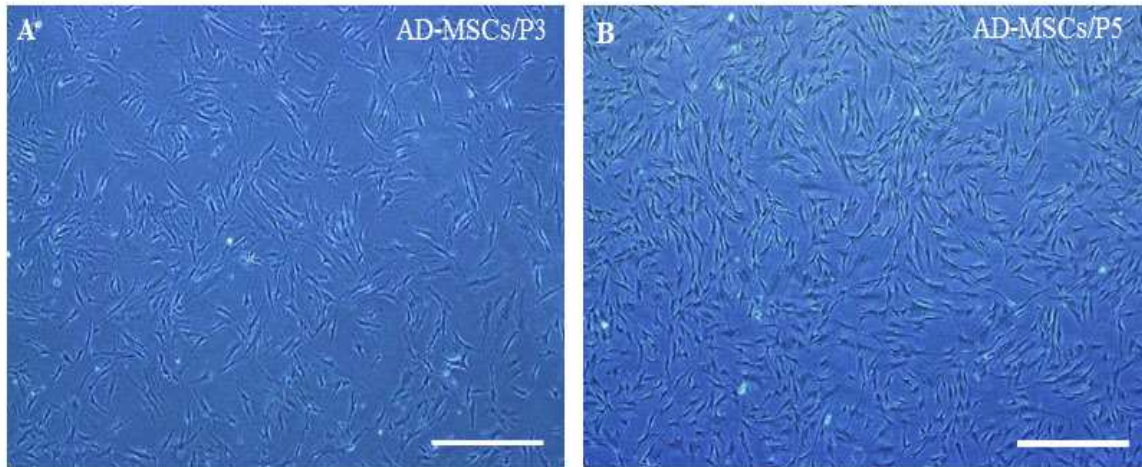


Fig.1. Human AD- MSCs with fibroblast-like morphology. (A) AD-MSCs passage 3, day 2. (B) AD-MSCs passage 5, day 4. Scale bars: 100 μm .

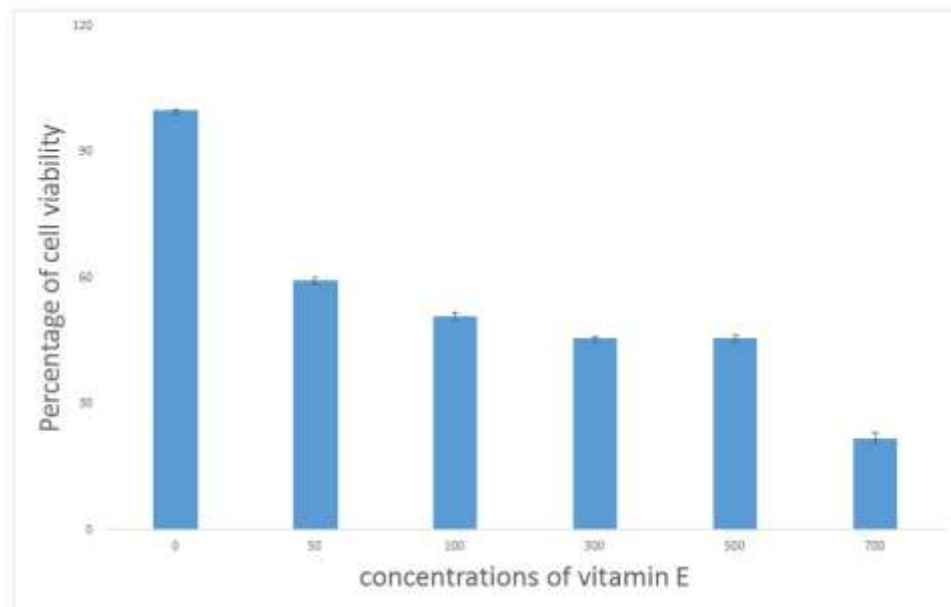


Fig. 2. Percentage of cell viability treatment with vitamin E

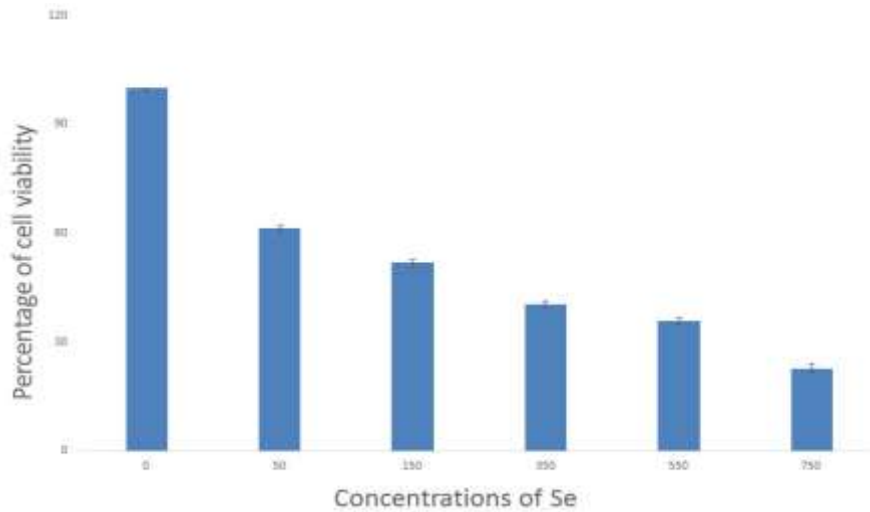


Fig. 3. . Percentage of cell viability treatment with Selenium (Se)

Osteogenic and adipogenic differentiation of MSCs whit vitamin E and Selenium treatment

Following the investigation, the effect of vitamin E and Selenium on cell proliferation, their impact on AD-MSCs differentiation potential was examined. Human AD-MSCs induced to differentiate in the presence and absence of the optimal dosages of vitamin E

and Selenium. Following differentiation induction, Alizarin red staining showed mineralization of the matrix occurred in vitamin E, and Selenium treated cells more than the control group (Fig 4 A, B, C). Similarly, Oil-red staining confirmed better adipogenesis induction in the treated cells in comparison with the control group (Fig. 4 D, E, F).

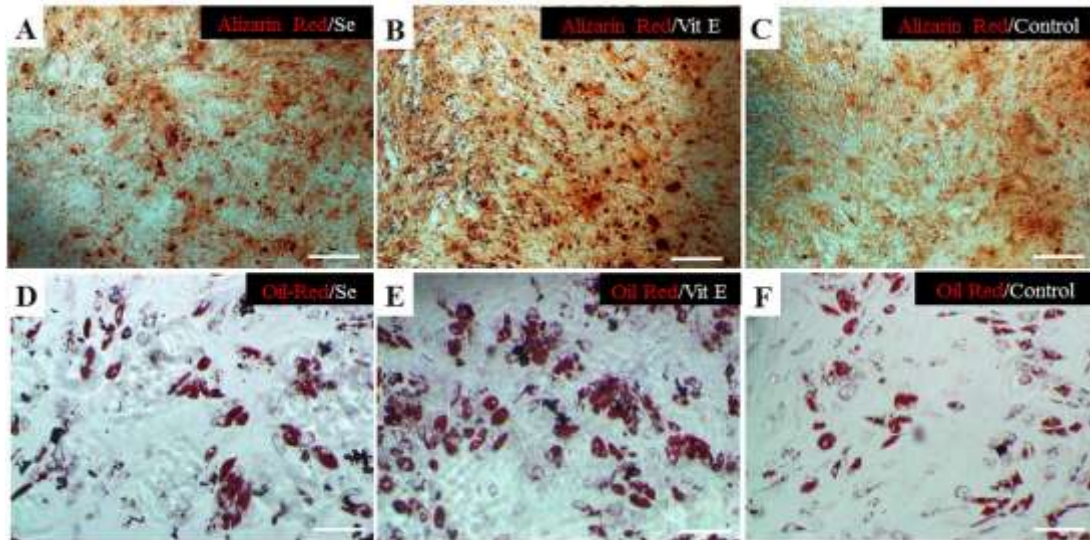


Fig. 4. Osteogenic and adipogenic differentiation of AD-MSCs. (A) Osteogenic differentiation using IC50 dose of Se. (B) Osteogenic differentiation using IC50 dose of vitamin E (Vit E). (C) Osteogenic differentiation of control group. (D) Adipogenic differentiation using IC50 dose of Selenium (Se). (E) Adipogenic differentiation using IC₅₀ dose of vitamin E. (F) Adipogenic differentiation of control group. Scale bars: 100µm.

Discussion

In this study, we have examined the antioxidant properties of the Selenium and vitamin E on the AD-MSCs stemness features. Our data indicate that both Selenium and vitamin E induce osteogenesis and adipogenesis in AD-MSCs in their IC₅₀ dosages. Furthermore, it seems that Selenium and vitamin E can improve the proliferation condition of the AD-MSCs *in vitro*.

Previous reports have shown that antioxidants such including vitamin E and Selenium have ROS scavenger potential, which can affect the proliferation and differentiation of MSCs. Moreover, the survival of MSCs against oxidative stress is vital for future cell therapy and tissue engineering [3]. Studies on other antioxidants such as melatonin, vitamin C, epigallocatechin-3-gallate have shown increase differentiation and proliferation of MSCs [22-25]. Here, we have investigated whether vitamin E and Selenium play a similar role in the proliferation and differentiation capacity of the AD-MSCs.

ROS is one of the essential biological elements with a critical role in the metabolic function of the cells. In this regard, interrupts in ROS production can cause cell damages including, apoptosis and release of inflammatory mediators and, subsequently, cell death [13, 26]. Besides, oxidative stress-induced the decline of cellular alkaline phosphatase an activity which caused decrease osteogenic differentiation potential of MSCs [23]. These ROS damaging effects mediated by antioxidant systems [26] so that treatment with

antioxidants such as Vitamin E induced MSCs to deactivate the effects of H₂O₂-induced oxidative stress [27]. Several studies confirmed the effect of Vitamin C and D on the differentiation of MSCs into adipogenesis and osteogenesis [24, 28, 29]. Previous research showed supplementation with vitamin E can protect against free radical, also enhanced cell proliferation and gene expression such as alkaline phosphatase, transforming growth factor-beta 1, fibroblast growth factor receptor 1, when compared to MSCs cultured in media without vitamin E [30]. but some study indicated that vitamin E inhibits differentiation of osteoblasts isolated from rat [31].

Vitamin E also can enhance the efficiency of neural stem cell differentiation and promotes morphological maturation of the differentiated neurons [32]. Herein, it was investigated that vitamin E can improve the differentiation potential of the AD-MSCs to osteogenic and adipogenic cells. 125 µM concentration was the effective dosage for differentiation using vitamin E. Previous findings indicated the positive effect of the Selenium considering as another antioxidant for adipogenic differentiation of primary pig and rat preadipocytes [33-35].

Recently study specified that Selenium nanoparticles are used for stem cell research, shown that enhance the differentiation of MSCs toward osteogenic lineage over adipocytes by promoting osteogenic transcription [36]. Adipose tissue-derived

stromal cells treated with Selenium results in differentiation into mesodermal and neural lineage [37]. Moreover, Selenium containing agents which can be promoted regeneration and normalization of osteogenesis [38]. The present study has shown not only maximum lipid droplet accumulation at 121 μ M concentration of Selenium but also higher matrix mineralization was detected with Selenium treatment in comparison with the control group.

Conclusion

Stem cells have generated a great deal in tissue engineering and regenerative medicine. In sum, the present study suggested vitamin E and Selenium due to antioxidant properties affect positively on the proliferation and

differentiation induction of the AD-MSCs. According to our results, these antioxidants can be used to optimize the differentiation condition for osteogenesis and adipogenesis. AD-MSCs are considered as a suitable candidate for future cell therapy and subsequent regenerative medicine applications. We hope this study could be an approach to cell therapy.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

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