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Article

Effect of physical exercise on the proliferation and inactivation capacity of biological immune cells

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Abstract: Objective: Exploring the effects of sport on the proliferation and inactivation of biological immune cells. **Method:** Sixty college students enrolled in a university between 1 March 2023 and 1 June 2023 were selected for the experiment. A total of 30 subjects were screened based on exclusion and inclusion criteria. The 30 subjects were evaluated and categorized into three experimental groups: Low-intensity physical activity, high-intensity physical activity and no physical activity. The three groups were tested for a period of 10 weeks, and the changes in cell survival rate, proliferation and inactivation capacity of macrophages, t-lymphocytes and dendritic cells were analyzed in the three groups. **Result:** There was a statistically significant difference ($P < 0.05$) in the pre- and post-experimental comparison of the different immune cells in the low-intensity physical exercise group. Only dendritic cell differentiation and survival rate were statistically significantly different in the pre- and post-experiment comparisons of high-intensity physical exercise ($P < 0.05$). **Conclusion:** Low-intensity physical exercise can significantly increase the proliferation and inactivation capacity of immune cells, which has a significant effect on the immune system of the organism.

Keywords: immune cells; physical exercise; cell proliferation; inactivation capacity; survival rate

1. Introduction

In recent years, with the continuous improvement of health awareness, physical activity as a natural and effective means of health promotion has received widespread attention in different fields. Exercise not only enhances cardiopulmonary function and improves metabolic status, but also has a significant effect on the regulation of the immune system [1]. The immune system, as an important barrier against pathogens in the human body, plays an important role in resisting infection, removing diseased cells and maintaining homeostasis in the body. Moreover, the proliferative capacity and inactivation function of cells such as t-lymphocyte, macrophage and natural killer cells are directly related to the immune efficacy of the organism, which determines the level of individual defense against diseases [2]. Several studies have now shown that moderate physical activity can significantly increase the activity of immune cells (IC) and promote their proliferation and functional enhancement. However, excessive exercise may trigger immunosuppression and reduce immune function instead [3]. Therefore, it is of considerable practical importance and applied value to elucidate the effects of disparate types and intensities of physical exercise on the proliferation and inactivation capacity of IC. In this regard, the study employs an innovative approach to analyze the effects of various types and intensities of physical exercise on the proliferation and inactivation capacity of a multitude of IC, thereby verifying the

specific mechanism of action through empirical data. This not only helps to explore the influence mechanism of physical exercise in the regulation of immune function, but also provides a new theoretical basis for the development of personalized body immune system enhancement programs.

2. Methods and materials

2.1. Subjects of the study and criteria for exclusion

The study selected 60 students enrolled in a university during the period from 1 March 2023 to 1 June 2023 as the study subjects. Inclusion Criteria: (1) Subjects were in good health and had not undergone major surgery; (2) the subjects themselves did not have chronic diseases [4]; (3) The subjects did not have major immunodeficiencies; (4) Subjects voluntarily participate in this study and sign the informed consent [5].

Exclusion Criteria: (1) Large physical exercise injuries during the study period and inability to perform subsequent studies; (2) the subject has a major immunodeficiency disease [6]; (3) The subject has previous experience of treatment for immunodeficiency diseases; (4) subjects voluntarily withdrew from the experiment during their participation [7]. A total of 30 out of 60 college students were screened for the study based on inclusion and exclusion criteria. The study divided the 30 equally into three groups, of which 10 subjects were in each group.

In addition to safeguarding against exercise changes, subjects will maintain their usual dietary habits during the experiment to avoid major dietary changes. At the same time, the subjects will also need to maintain a stable sleep pattern during the experiment to avoid excessive sleep or sleep deprivation. The subjects will also be required to maintain a healthy psychological state during the experiment to ensure that no major psychological stress or changes occur.

2.2. Research methods

The experiment’s inclusion and exclusion criteria were used to choose 30 participants for the investigation. Ten subjects each were split up into three groups: two experimental groups (EGs) and one control group (CG). During this time, the recommended aerobic exercise routine was carried out at a low intensity [8]. The EG 2 consisted of 10 people, during the conduct of the experiment the sport was divided into, high intensity and low intensity. The CG consisted of 10 people and did not participate in any other physical exercise during the experiment. The three groups of subjects were tested for a total of 10 weeks. The groups that participated in physical exercise participated in physical exercise on Tuesdays, Thursdays, and Fridays of each week, and the duration of the physical exercise lasted one and a half hours [9]. Blood was collected and analyzed from each group of subjects before the start of the test, as well as during the 5th week of testing and after the completion of the test. The intensity of physical activity was referred to the metabolic equivalent of Tas (METs) table, where 1 MET stands for 1 mL of oxygen/kg of body weight per minute, which represents the energy expenditure during the resting state [10]. Exercise is indicated

as LIPE when it consumes less than 3METs and LIPE when it consumes more than 6METs. The groups studied are shown in **Table 1**.

Table 1. Basic information on study groups.

Group	Training content	Rest time	Metabolic equivalent Tas (METs)	Schedule
EG 1	Jogging, jumping rope, and yoga	5 min	Below 3 METs	Tuesday, Thursday, and Friday
EG 2	Rope skipping, long-distance running, and bike riding	5 min	Above 6 METs	
CG	No additional physical exercise	/	/	/

In **Table 1**, the different groups in the EG 1 physical exercise included low-intensity physical exercises (LIPE) such as jogging, jumping rope, and yoga. The METs of each exercise were maintained below 3METs, and 5 min of rest was taken between each exercise group [11]. EG 2 physical exercise included high-intensity physical exercise (HIPE) such as jumping rope, long-distance running, and bicycle riding. The METs per exercise were maintained above 6METs, and the rest time between physical exercise groups was 5 min. The CG did not perform additional physical exercise [12]. The study used a combination of heart rate monitoring, subjective exertion scales, and METs assessment in order to guarantee that the exercise intensity of each group was in accordance with current standard METs values. Each participant was equipped with a polar heart rate monitor (Polar Electro Oy, Finland), which provided real-time heart rate data and was used to estimate energy expenditure and the corresponding METs. In addition to heart rate monitoring, the Borg Rating of Perceived Exertion (RPE) scale was used during the experiment to rate the degree of perceived exertion of the experimenters. All exercise sessions were supervised by trained personnel during the experiment, and the exercise program was adjusted in real time based on heart rate monitor and RPE feedback to ensure that target METs values were achieved and maintained over the 10-week study period.

2.3. Methods of cell extraction from blood

The IC chosen for testing in the study are t-lymphocyte and macrophages. Each set of experiments will be conducted before and after the different exercises are performed, where the blood samples will be collected in a volume of 4 mL. The study samples the blood of the subjects after the 5th and 10th week of physical exercise, respectively. Blood was collected using 8 mL tubes of ethylenediaminetetraacetic acid (EDTA). The collected blood samples were placed in a centrifuge for centrifugation for 10 min to separate blood and plasma first [13]. Once the blood and plasma were separated the plasma in the blood sample was separated using a 1 mL pipette gun, retaining the blood component and a small amount of plasma components. The blood sample was poured into a new centrifuge tube (CT) and Hank's balanced salt solution with EDTA (HBSS-EDTA) was added to fill the CT, which was inverted and flicked to dissolve the remaining blood. The tube was inverted and flicked to dissolve the remaining blood, and 15 mL of Percoll solution was aspirated into a 50 mL CT, then transferred and centrifuged again when finished. At the end of centrifugation, the cell bands were collected. The cell bands were resuspended and centrifuged using HBSS-

EDTA solution [14]. Finally, after centrifugation was completed the culture medium was used for resuspension and the number of cells was counted.

The study uses a standardized cell counting method where cells are counted using a blood cell counter under a light microscope at 100 x magnification. First the cells were re-suspended in RPMI 1640 after the cells had gone through the isolation and sorting process, and the suspension concentration ensured that the cells could be accurately counted within the grid of the cell counting chamber. Next, a small amount (10 μL) of the cell suspension was carefully loaded into the counting chamber and left to stand for 2 min. The cells within the grid were then manually counted. At the same time each cell suspension is counted three times and the average value is taken as a representative value of the sample. Finally, the cell counts at different time points were compared to assess the proliferation rate of T lymphocytes and macrophages.

2.4. Cell sorting process

In preparing the solution, the peripheral blood single nucleated cell (SNC) preparation solution was used first. SNCs were extracted from 10 mL of peripheral blood, and the peripheral blood SNCs were washed with a mixture of 50 mL of phosphate-buffered saline (PBS) + 3.0 mL of human albumin + 800 μL of EDTA. Centrifugation at 400 g for 10 min was used to remove and discard the supernatant [15]. After completion of centrifugation the peripheral blood SNCs were washed twice with PBS + 2% human serum albumin and centrifuged again after each wash.

Sorting of t-lymphocyte: firstly, the cell suspension (CS) was incubated with magnetic bead-labeled antibody against CD3 antigen for 15 min at the recommended ratio and conditions according to the instructions [16]. At the end of the incubation, the suspension was centrifuged and the supernatant was discarded. Cells were washed with a mixture of PBS + EDTA + human albumin and centrifuged to remove the washings. The CS was added to a pre-treated sorting column and the fraction of labeled T cells was separated by a magnetic column. T cells were eluted from the magnetic column using PBS buffer, and the number of t-lymphocytes was collected and counted. The isolated t-lymphocytes were resuspended in Roswell Park Memorial Institute 1640 Medium (RPMI 1640) to prepare for subsequent experiments.

Macrophage sorting: the remaining CS was labeled with Macrophage Sorting CD14 Antibody, and after labeling, the CS was incubated again for 15 min. The cells were separated using a macrophage sorting column once the incubation was finished, and the supernatant was extracted by centrifugation. The cells were then rinsed with PBS. Macrophages were eluted from the column and collected. Two more washes were performed to ensure that there were almost only macrophages in the sample. After collecting the macrophages, they were resuspended in RPMI 1640 medium and the cells were counted and prepared for subsequent experiments.

Dendritic cell sorting: a suspension of collected SNCs was prepared and specific antibodies for labeling dendritic cells were added. The incubations were performed according to the recommended ratios in the kit instructions. The incubation time was typically 15 min at 4 °C to avoid light. The CS was centrifuged and the supernatant was disposed of once the incubation was finished. The cells were then gently washed with a mixture of PBS + EDTA + human serum albumin to ensure removal of unbound

antibodies. The washings were removed by centrifugation again. The washed CS was added to a pre-treated dendritic cell sorting column, and the dendritic cells were separated by magnetic sorting column. Dendritic cells were eluted from the magnetic column using PBS buffer and the eluate was collected. To ensure the purity of the dendritic cells, the washing step can be repeated twice to ensure that there are almost only dendritic cells in the sample. The collected dendritic cells are resuspended using RPMI 1640 medium to ensure that the cells are in good condition. The number of dendritic cells was then counted in preparation for subsequent experiments.

2.5. In vitro cell culture methods

When t-lymphocyte was cultured, 1.0 mL of t-lymphocyte was aspirated and mixed with a pipette gun, and 20 μL was removed for cell counting. The T cells were distributed in 6-well plate culture flasks with an area of 25 cm^2. Magnetic beads labeled with anti-CD3 and anti-CD28 antibodies were added to the well plates to activate t-lymphocyte for proliferation. Finally, T-cells were collected and transferred to 50 mL CTs and centrifuged for 8 min, and the supernatant was discarded after completion of centrifugation [17]. The cells were washed with a solution prepared with PBS solution and 2% human serum protein.

During macrophage culture, the medium needs to be pre-warmed first, and the isolated macrophage cells were added into RPMI 1640 medium and pre-warmed in a 37 ℃ water bath for 10 min. Cells were aspirated with a 1.0 mL pipette gun and 20 μL were removed for cell counting. Macrophages were distributed in 6-well plates with a culture area of 25 cm^2 in culture flasks. M-CSF (macrophage colony-stimulating factor) can be added to promote macrophage maturation and proliferation during macrophage culture. Following cell collection, the macrophages were isolated for further research after the cells were spun and cleaned using PBS and a 1.5% human serum protein solution.

2.6. Statistical methods

SPSS 25.0 software was used to statistically evaluate the study's data, and one-way analysis of variance for each group was used to examine the data indicators pertaining to IC. $P < 0.05$ displays that there is a statistically significant difference (SSD).

3. Results

3.1. Comparison of general baseline information

The study compared the baseline profile of the students in different groups such as age, height, weight and blood pressure. **Table 2** shows the general baseline profile of the subjects.

Table 2. Comparison of general baseline data of the three groups of patients.

Content	EG 1	EG 2	CG	*F*	*P*
Age (years)	19.85 ± 0.48	19.87 ± 0.42	199.75 ± 0.42	0.076	0.842
Height (cm)	172.52 ± 3.26	173.48 ± 4.02	172.23 ± 4.36	0.223	0.736
Weight (kg)	67.89 ± 5.26	68.42 ± 4.36	68.73 ± 4.67	0.165	0.785
Heart index	5.68 ± 1.10	6.21 ± 2.34	6.35 ± 1.64	0.326	0.669
Systolic pressure (mmHg)	119.25 ± 3.48	122.53 ± 5.16	119.52 ± 5.62	0.153	0.768
Diastolic pressure (mmHg)	81.15 ± 3.15	78.92 ± 4.75	79.63 ± 4.69	0.085	0.832
Gender (male/female)	6/4	5/5	4/6	0.162	0.736

In **Table 2**, in the comparison of general baseline information of subjects in different groups, there was no SSD ($P > 0.05$) in the general data information such as age, height, and weight and blood pressure of subjects in all three groups. This indicates that there is no SSD in general data information between subjects in different groups. Moreover, only the EG and CG of participants had a numerically different number of men and women when comparing the gender gap across the three groups.

3.2. Changes in t-lymphocyte survival rate in different groups

To analyze the survival of t-lymphocyte in subjects during different periods of the experiment, the cell survival during the experiment was compared. **Table 3** depicts the details.

Table 3. Comparison of t-lymphocyte survival rates.

Group	T-lymphocyte survival before the start of the experiment (%)	T-lymphocyte survival 5 weeks after the start of the experiment (%)	T-lymphocyte survival after completion of the experiment (%)	*F*	*P*
EG 1	91.22 ± 0.68	92.05 ± 1.35	93.50 ± 1.10	13.57	0.001
EG 2	91.25 ± 1.42	91.68 ± 0.35	92.12 ± 0.95	/	/
CG	91.33 ± 0.86	91.52 ± 1.15	92.86 ± 1.12	/	/

In **Table 3**, in the comparison of the three groups of subjects, the t-lymphocyte survival rate of subjects in different groups increased with time. Among the three groups of subjects, the highest t-lymphocyte survival rate of EG 1 could reach 93.50 ± 1.10%, while the lowest t-lymphocyte survival rate of subjects in EG 2 was only 92.12 ± 0.95%. In the comparison of t-lymphocyte survival rate between the three groups of subjects before and after the experiment, only the EG 1 had a SSD ($P < 0.05$), while there was no SSD in the rest of the two groups ($P > 0.05$). This suggests that LIPE can effectively enhance the activity of IC and improve the cell survival rate of the subjects.

3.3. Comparison of the proliferative effects of different groups of t-lymphocyte cells

To compare the changes of cell proliferation situation of different EGs in the time period, the study compared and analyzed the proliferation situation of t-lymphocyte in different groups. The outcomes of the comparison of the cell growth scenario are displayed in **Figure 1**.

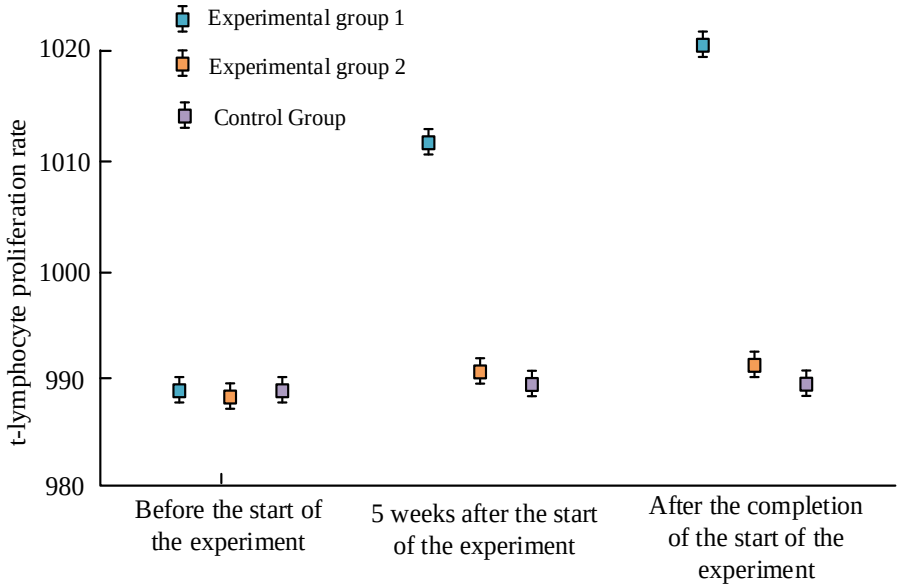

Figure 1. Comparison of t-lymphocyte proliferation folds in different groups of subjects.

Figure 1 shows the comparison of t-lymphocyte proliferation in different groups. The subjects in the LIPE group had a maximum IC proliferation rate of 1021.42 ± 4.01. In the LIPE group, the lymphocytes had a maximum proliferation rate of 992.24 ± 8.65, whereas the CG had a maximum cell proliferation rate of 989.90 ± 2.68. There was a SSD ($P < 0.05$) between the cell proliferation multiplicity of the EG 1 subjects in the comparison of the three groups of subjects. It can be observed that LIPE can effectively enhance the proliferation capacity of t-lymphocyte.

3.4. Comparison of inactivation function of different groups of t-lymphocyte

To compare the inactivation function of t-lymphocyte between different groups, the study analyzed the inactivation function of cells from different groups, as displayed in **Table 4**.

Table 4. Comparison of the inactivation of t-lymphocytes in different groups.

Group	Target ratio	T-lymphocyte survival before the start of the experiment (%)	T-lymphocyte survival 5 weeks after the start of the experiment (%)	T-lymphocyte survival after completion of the experiment (%)	*F*	*P*
EG 1	1:4	8.95 ± 0.32	10.35 ± 0.36	11.52 ± 0.42	25.88	0.000
	4:1	81.26 ± 2.14	83.62 ± 1.48	84.50 ± 1.32	18.68	0.001
EG 2	1:4	9.05 ± 0.57	10.68 ± 0.48	10.78 ± 0.63	/	/
	4:1	82.27 ± 2.81	83.42 ± 2.54	84.25 ± 2.62	/	/
CG	1:4	9.12 ± 0.27	9.35 ± 0.46	9.66 ± 0.35	/	/
	4:1	82.25 ± 2.75	83.06 ± 2.42	83.90 ± 2.52	/	/

In **Table 4**, the cellular inactivation function of subjects who underwent LIPE was more prominent in the comparison of t-lymphocyte inactivation function in different groups of subjects. The cellular inactivation function of low-target ratio was

able to reach 11.52 ± 0.42%, while the cellular inactivation function of high-target ratio was able to reach 84.50 ± 1.32. Meanwhile, there is a SSD between the inactivation function of different target ratios before and after the experiment ($P < 0.05$). There was no SSD in cellular inactivation function before and after the experimental comparison between LIPE and the CG ($P > 0.05$). Thus, LIPE can substantially enhance t-lymphocyte inactivation activity.

3.5. Changes in macrophage survival rate in different groups

The macrophage survival of the subjects during the different periods was analyzed and the macrophage survival during the experimental period was compared as shown in **Table 5**.

Table 5. Comparison of macrophage survival.

Group	Macrophage survival before the start of the experiment (%)	Macrophage survival 5 weeks after the start of the experiment (%)	Macrophage survival rate at the end of the experiment (%)	*F*	*P*
EG 1	92.57 ± 0.48	93.42 ± 1.46	94.42 ± 1.24	12.85	0.000
EG 2	92.24 ± 1.46	92.68 ± 0.35	92.75 ± 0.67	/	/
CG	92.35 ± 0.89	92.52 ± 1.32	92.53 ± 1.06	/	/

In **Table 5**, the highest macrophage survival rate of the LIPE group was able to reach 94.42 ± 1.24% in the macrophage survival analysis. At the same time, there was a SSD in the cell survival rate before and after the experiment ($P < 0.05$). At the same time, there was no SSD in cell survival rate between the other groups ($P > 0.05$). It can be concluded that LIPE in different groups can effectively enhance the cell survival rate of the subjects.

3.6. Comparison of macrophage proliferation in different groups

In order to compare the cell proliferation of macrophages between different groups, the cell proliferation multiplicity between different groups was comparatively analyzed, as shown in **Figure 2**.

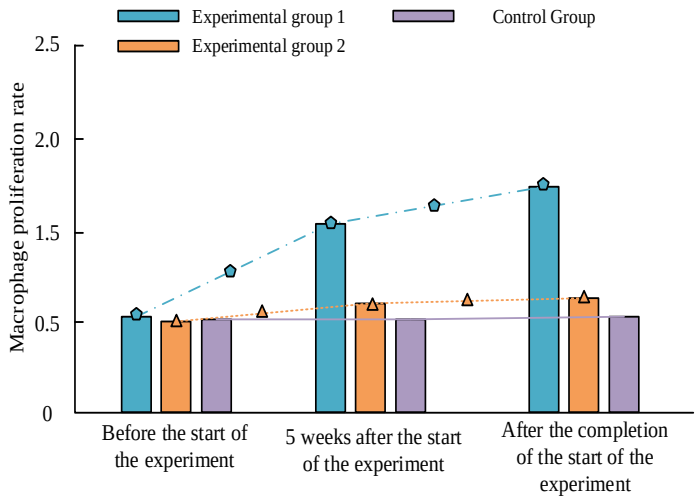

Figure 2. Comparison of macrophage proliferation multiplicity.

In **Figure 2**, in the comparison of macrophage proliferation folds, the proliferative effect of LIPE on macrophages was enhanced. In this case, the proliferation fold of macrophages was 1.62 ± 0.35 at the end of the experiment, while there was a SSD between the proliferation fold of cells before and after the experiment ($P < 0.05$). While there was no SSD in proliferation multiplicity between the other groups ($P > 0.05$).

3.7. Comparison of macrophage inactivation function in different groups

To compare the inactivation function of macrophages in different groups, the study analyzed the rate of cellular inactivation in different groups, as shown in **Table 6**.

Table 6. Comparison of macrophage inactivation in different groups.

Group	Target ratio	Macrophage survival before the start of the experiment (%)	Macrophage survival 5 weeks after the start of the experiment (%)	Macrophage survival rate at the end of the experiment (%)	*F*	*P*
EG 1	1:4	12.58 ± 0.15	14.58 ± 0.38	16.24 ± 0.26	24.75	0.00,1
	4:1	84.85 ± 2.35	87.35 ± 2.52	89.50 ± 1.26	16.24	0.000
EG 2	1:4	12.54 ± 0.48	12.42 ± 0.65	13.88 ± 0.48	/	/
	4:1	84.25 ± 2.48	83.42 ± 2.54	84.25 ± 2.62	/	/
CG	1:4	12.15 ± 0.27	12.85 ± 0.36	12.48 ± 0.35	/	/
	4:1	84.24 ± 2.58	84.42 ± 2.15	84.48 ± 2.23	/	/

In **Table 6**, in the comparison of the inactivation function of macrophages before and after physical exercise, there was a SSD ($P < 0.05$) in the inactivation function of macrophages before and after the experiment with LIPE. This indicated that LIPE have a significant enhancement effect on macrophage inactivation. However, there was no SSD between LIPE and groups without physical exercise, which showed that the intensity of physical exercise also has an effect on the inactivation left and right of the cells.

3.8. Changes in dendritic cell survival rate in different groups

To analyze the survival of dendritic IC under different groups, the study compared the survival rate of different groups, as shown in **Table 7**.

Table 7. Comparison of dendritic cell survival in different groups.

Group	Dendritic cell survival before the start of the experiment (%)	Dendritic cell survival 5 weeks after the start of the experiment (%)	Survival of dendritic cells at the end of the experiment (%)	*F*	*P*
EG 1	90.25 ± 0.72	82.52 ± 1.25	94.24 ± 1.35	9.85	0.002
EG 2	90.42 ± 1.84	88.24 ± 0.46	92.04 ± 0.68	8.62	0.003
CG	90.42 ± 0.75	90.66 ± 1.48	90.25 ± 1.24	/	/

In **Table 7**, there was a SSD ($P < 0.05$) in the survival rate of dendritic cells after both low-intensity and LIPE. In contrast, there was no SSD in the survival rate of dendritic cells in the CG. The survival rate of dendritic cells during LIPE also showed a decreasing trend at week 5, but then their survival rate increased significantly. This

is due to the fact that LIPE may lead to a decrease in the survival rate of dendritic cells in the short term, but may contribute to an increase in the survival rate of dendritic cells after long-term acclimatization.

3.9. Differentiation of dendritic cells in different groups

To compare the differentiation efficiency (DE) of dendritic cells under different groups, the study analyzed the DE of dendritic cells in a comparative analysis obtained as shown in **Figure 3**.

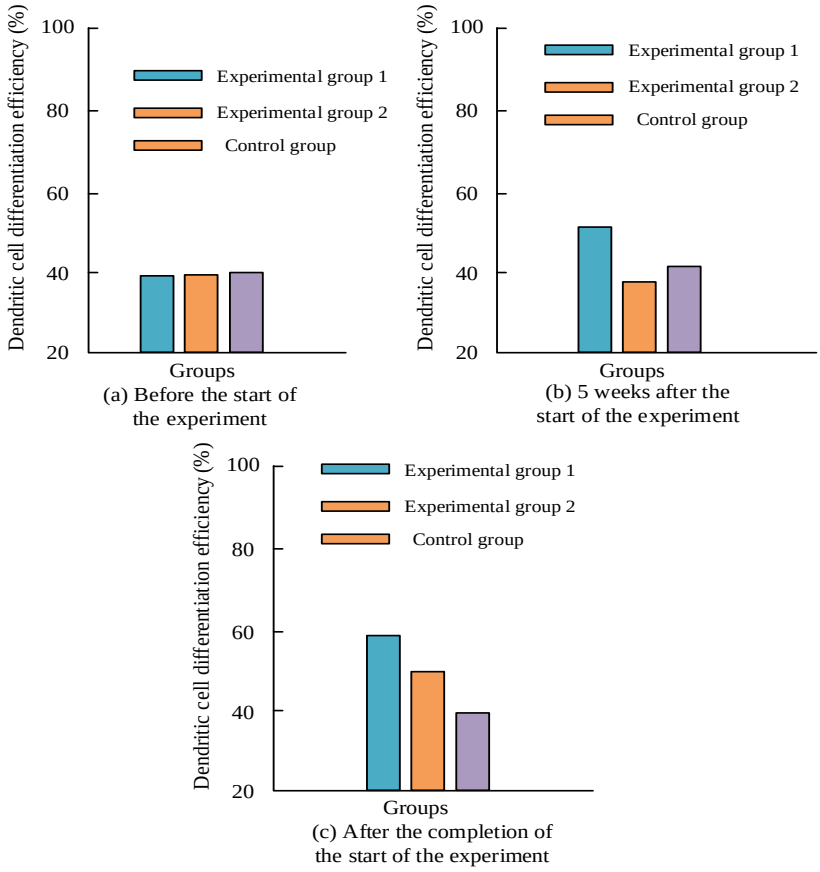

Figure 3. Comparison of DE of dendritic cells.

In the comparison of **Figure 3a–c**, the DE of dendritic cells by LIPE was able to reach a maximum of 61.25% in the change of DE, while the CG basically did not show any increase in the DE of their cells. In the LIPE group, the DE of the cells decreased in the 5th week, which may be due to the cells' inability to adapt to the changes in the body. Meanwhile, there was a SSD between the cell differentiation efficiencies of the EGs both before and after the experiment ($P < 0.05$).

3.10. Comparison of cell activation efficiency of dendritic cells in different groups

Since dendritic cells cannot directly perform cell inactivation function, the study only compared their activation activation efficiency on t cells. **Table 8** displays the comparing results.

Table 8. Comparison of dendritic cell activation efficiency in different groups.

Group	Dendritic cell survival before the start of the experiment (%)	Dendritic cell survival 5 weeks after the start of the experiment (%)	Survival of dendritic cells at the end of the experiment (%)	*F*	*P*
EG 1	72.36 ± 0.52	74.74 ± 1.48	76.15 ± 1.21	9.68	0.004
EG 2	72.58 ± 1.24	70.12 ± 0.36	73.58 ± 0.48	/	/
CG	72.24 ± 0.68	72.48 ± 1.57	72.84 ± 1.48	/	/

In **Table 8**, in the comparison of cell activation activation efficiency of dendritic cells, LIPE had a positive effect on the activation efficiency enhancement of cells. There was a SSD in their activation efficiency before and after the experiment ($P < 0.05$). Meanwhile, the activation efficiency of cells in LIPE showed a decreasing trend, but there was no SSD in the activation efficiency before and after the experiments in the CG and LIPE. This may be due to the reason that high intensity physical exercise have an effect on the activation performance of the cells.

3.11. Comparison of cytokine secretion in dendritic cells of different groups

To ascertain the impact of physical activity on the proliferative differentiation of dendritic cells, the study evaluated the cytokine secretion of dendritic cells under various conditions. The released factor was identified as IL-2. **Table 9** displays the comparison's findings.

Table 9. Comparison of cytokine secretion in different groups of dendritic cells.

Group	Dendritic cell survival before the start of the experiment (pg/mL)	Dendritic cell survival 5 weeks after the start of the experiment (pg/mL)	Survival of dendritic cells at the end of the experiment (pg/mL)	*F*	*P*
EG 1	300.58 ± 68.95	426.24 ± 75.68	496.58 ± 86.52	10.35	0.002
EG 2	301.51 ± 67.52	272.58 ± 62.35	368.04 ± 76.52	/	/
CG	300.86 ± 72.35	312.34 ± 71.56	309.48 ± 70.35	/	/

In **Table 9**, in the comparison of the amount of cellular IL-2 factor, LIPE had a greater effect on the IL-2 factor in the cells, and there was a SSD between their pre- and post-experiments ($P < 0.05$). In contrast, there was no SSD ($P > 0.05$) in the change of IL-2 factor between LIPE and the CG. It can be concluded that LIPE can significantly affect the activity of dendritic cells.

4. Discussion and conclusion

The immune system is the body's vital defense against foreign pathogens. T-lymphocytes, macrophages, and dendritic cells are important parts of the immune system that are involved in phagocytosis, antigen presentation, and cellular immunity, respectively. Because of this, numerous research have been carried out to look into how various IC proliferate and deactivate during physical activity and in people. For example, in a study by Fiuza-Luces C et al. it was found that regular physical activity significantly enhanced the tumor suppressive effect of IC, and that post-exercise blood could be used in cancer therapy [18]. It was found that physical exercise could significantly enhance the immune effect of cells. However, how cells enhance immune

performance needs to be further explored. For this reason, to examine how physical activity affects IC' ability to work better, the current study examined the proliferation and inactivation capabilities of IC. García-Chico C et al. found that cancer cells induced a variety of cell physiological mechanisms, so the relationship between the proliferation of the remaining cells through physical exercise can be more effective in the treatment of cancer [19]. However, the study only analyzed cancer cells, and the effect of physical exercise on biological IC needs to be further explored. The objective of the study was to investigate the proliferation and inactivation functions of human macrophages, dendritic cells, and t-lymphocytes, as well as to analyze the association between physical exercise and various IC functions within the human body. Murugathasan et al.'s study investigated the effect of physical exercise on macrophage metabolism in mice and showed that appropriate physical activity can reduce inflammation and enhance macrophage metabolism in mice [20]. Therefore, the current study investigated the proliferation and inactivation capacity of macrophages on this basis.

The outcomes revealed that in the general baseline comparison of the subjects, there was no SSD ($P > 0.05$) in the baseline information of the different groups. In the pre- and post-experiment comparisons of t-lymphocyte and macrophage cells in subjects, a SSD was found in the survival rate of the two types of cells before and after the low-intensity physical activity experiment ($P < 0.05$). This indicated that the cell survival rate of t-lymphocyte and macrophage was better during LIPE. t-lymphocyte and macrophage proliferation multiplicity was statistically significantly different before and after the experiment during LIPE ($P < 0.05$). However, there was no SSD in the proliferation folds of both cells before and after the experiment when performing LIPE and when not performing physical exercise ($P > 0.05$). This indicated that LIPE had less effect on the proliferative effect of IC. In the comparison of the differentiation of dendritic cells before and after the experiment, there was a SSD ($P < 0.05$) difference in the differentiation capacity of cells between LIPE and LIPE before and after the experiment. This indicated that physical exercise could enhance the differentiation capacity of dendritic cells. In the comparison of dendritic cell activation efficiency and the amount of IL-2 factor, there was a SSD between LIPE in both pre- and post-experimental comparisons ($P < 0.05$). Whereas, there was no SSD between high intensity physical exercise and no physical exercise before and after the experiment ($P > 0.05$). It was evident that LIPE had a positive effect on cell activation efficiency and IL-2 factor effects on dendritic cells. In the results of the study, it was found that HIPE had less effect on immune cell proliferation and survival compared to the HIPE group with LIPE. This suggests that high-intensity physical activity may trigger immunosuppression and reduce immune function. This may be due to the fact that HIPE leads to a transient elevation of systemic stress hormones such as cortisol, which has immunosuppressive effects. High levels of cortisol inhibit the production and function of immune cells, which may be responsible for the reduced cell survival and proliferation in the HIPE group. Also, strenuous exercise increases the production of ROS, which leads to cellular oxidative stress and damages cellular components. This may contribute to decreased cell survival and proliferation.

The data indicate that LIPE can enhance the proliferation and inactivation function of bioimmune cells. This may be due to the fact that LIPE increases the

oxidative capacity of immune cells and promotes a more efficient use of oxygen and nutrients, thus contributing to enhanced immune cell proliferation and function. Also, exercise may affect epigenetic modifications of cells such as DNA methylation and histone modifications. These epigenetic changes may regulate the expression of genes involved in immune cell function, thereby affecting cell proliferation and activation. LIPE activates the AMP-activated protein kinase (AMPK) pathway, which plays an important role in the regulation of cellular energy homeostasis and is capable of boosting cellular immunomodulation. However, the increase in the intensity of physical exercise has a less pronounced effect on cell proliferation and inactivation function. While this study has yielded some promising results, there are still some limitations that require further investigation. Subsequent studies will thus expand the scope to encompass a more diverse range of physical exercise and their impact on cell proliferation and inactivation functions. Furthermore, the impact of physical activity on additional immune cell mechanisms will be examined. Also in practical studies, seasonal changes in sunlight exposure, temperature and humidity affect the production of vitamin D, melatonin and other immune hormones in the body. For example, less sunlight in winter can lead to reduced vitamin D synthesis, which is associated with impaired immune function. Meanwhile lower temperature and humidity changes may affect the incidence of respiratory infections, which in turn affects the activity of immune cells. Therefore, in future studies, cellular research should also consider the effects of seasonal changes on immune function.

Practical applications can be made in health management by incorporating LIPE as a routine activity in public health strategies to reduce the incidence of common infections. A corresponding LIPE program can be developed for communities of different ages and fitness levels to encourage residents to engage in regular physical activity. Meanwhile, for immunocompromised people, it may be possible to enhance the function of immune cells and improve their immunity through the development of appropriate therapeutic assistance programs. Finally, in practical application, the study can also develop personalized exercise prescriptions based on the immune status and physical abilities of different populations. By tailoring exercise programs to meet the specific needs of individuals, the immune-boosting effects of physical activity can be optimized while minimizing the risk of over-exercise and associated immunosuppression.

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