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*Case Report*

# Elbow plank exercise improves immunocyte function and physical fitness in an elderly male: a case study

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**Abstract**

**Background**: The elbow plank is a common exercise that can easily be done at home, but its effects on physical fitness and immunocyte function in elderly people are unknown. This prior study was conducted to analyze the changes in health-related physical fitness and immunocytes in an elderly male subject after performing elbow plank exercises. **Methods**: The participant was a 61-year-old man who had no experience in performing the elbow plank. Elbow plank exercises were performed for 30 min a day, 5 days a week, for 4 weeks. The intensity of was checked daily with ratings of perceived exertion (RPE). His goal was to reach an RPE between 12 and 14, at which a 1 min rest was given before repeating the process with a progressively higher RPE every 10 min. **Results**: Compared with pre-values, (1) health related physical fitness factors increased after 4 weeks. (2) Body weight, skeletal muscle mass, and basal metabolic rate increased, whereas body fat mass and fat percentage decreased. (3) Certain variables of complete blood count showed positive changes, while others did not. Specifically, NK cells (CD56) and cytotoxicity were improved. **Conclusions**: This study confirmed that performing elbow plank exercises improved all factors of physical fitness and the immunocyte function in an elderly male. Therefore, 20.73 min (9.27 min of rest) of plank exercise is recommended for elderly men to prevent deterioration of physical fitness and immunocyte function while staying at home, especially during the COVID-19 pandemic.

**Keywords:** Plank exercise; Immunocyte; Physical fitness; NK cell; Cytotoxicity

## 1. Introduction

Currently, the world has enacted social distancing protocols, as well as limiting many physical gatherings and activities to reduce the transmission of COVID-19. Due to the pandemic, the time spent at home has greatly increased, while physical activity has sharply decreased, which can lead to increased rates of obesity and decreased immunocyte function to defend against substances such as viruses and bacteria. In particular, the elderly seems to be a high-risk group for the coronavirus, requiring more physical function management. Even for the general population, effective intervention methods are needed to break this cycle of disease by preventing obesity and improving immunocyte function during these times of increased isolation. Considering the need to practice social distancing, it is essential to find exercises that can be performed at home.

Exercise is an activity that is planned, structured, and repetitive, with the purpose of improving or maintaining one or more health-related components of physical fitness [1]. Physical exercise can effectively reduce body fat and prevent obesity by increasing skeletal muscle mass and basal metabolic rate, as well as improving immunocyte function. As the world deals with the current COVID-19 pandemic, exercise has become more necessary than ever before [2].

What exercises can an elderly person do alone at home? Recently, the plank exercise has gained much attention as a good exercise to increase calorie consumption in a short amount of time and to strengthen the core muscles around the abdomen and waist [3]. It is easy to learn, and requires little time, space, and cost. Plank exercises combine movements such as Pilates and yoga, and can be performed by anyone. In addition, since plank exercises can be used as a whole-body exercise, it is possible to consume a large number of calories in a short period of time and building muscle mass. The plank exercise refers to the movement of supporting the body by creating a piercing posture with the forearms and both feet contacting the ground [4]. It is known that increasing the exercise capacity of the abdominal muscles among the core muscles through plank exercises contributes toward improving body movement [3]. It can be said that it is an exercise that increases the activity of the core muscles and promotes core stabilization by maintaining the neutral posture of the human body [5].

Until now, performing planks have been known as a convenient exercise that can be done at home using the core muscles, but it is not known what kind of physical fitness benefits it provides, as well as its effects on immunocytes. In particular, it is not known whether this is a suitable exercise for the elderly. Therefore, this prior study investigated the effects of plank exercises on the health-related physical fitness components (body composition, strength, muscle endurance, flexibility, and cardiopulmonary endurance) and immunocyte function of an elderly man.

## 2. Materials and methods

### *2.1 Participant*

A 61-year-old Asian man (171.3 cm, 66.2 kg) with no chronic disease was considered. He had no experience in performing the elbow plank. He has not been on any medication and did not exercise for over 6 months. At the pre-experiment session, he was provided a diary to record what he consumed for breakfast, lunch, and dinner throughout the experimental period (4 weeks). An expert input the food type and volume in CAN-Pro 5.0 (The Korean Nutrition Society, Seoul, Korea) every day, calculated the caloric intake, and then performed an evaluation at the end of each week. The daily amount of physical activity that was performed outside the experiment was also recorded and calculated using the international physical activity questionnaire (IPAQ) - shortened form version [6]. An expert provided a diary to record the contents of the questionnaire on a daily basis. The participant answered the questionnaires based on the recordings of physical activities for the week throughout the experimental period. The daily calorie output was calculated by metabolic equivalent (MET)-Minutes (kcal/kg/min) at the end of every week. The total score was obtained through the summation of the duration (in minutes) and frequency (days) of walking (3.3 × min of activity/day × days per week), moderate-intensity activity (4.0 × min of activity/day × days per week), and vigorous-intensity activity (8.0 × min of activity/day × days per week). Then, using the data, the average amount of physical activity per week was calculated based on the IPAQ score conversion method [7]. These data were averaged on a weekly basis and analyzed every week.

### *2.2 Experimental design*

This was a prospective case study that compared pre-values with post-values and was conducted at Seoul Songdo Hospital from May 28 to June 26, 2021. The study is in accordance with the principles of the Declaration of Helsinki and received approval from the institutional ethics committee (2-1040781-A-N-012020085HR). Prior to the study, the principal investigator gave a detailed explanation of the procedures to the participant, who read and signed an informed consent form. The participant also completed a self-reported questionnaire about his health status and learned how to record the ratings of perceived exertion (RPE) in a diary [8]. The assessments were performed at week 0 and at week 4. The intervention program consisted of the elbow plank exercise, which was conducted for 4 weeks, 5 days a week, and 30 min a day.

### *2.3 Measurement methods*

#### 2.3.1 Blood sampling and immunocyte measures

This study investigated the changes of complete blood counts (CBC), lymphocyte, and granulocytes subsets. The percentage and absolute cell counts of peripheral blood cell subsets were analyzed as described below: 50 $\mu$L of blood were stained with anti-human antibodies against anti-CD3, anti-CD4, anti-CD8, and anti-CD56 from BD Biosciences (Franklin Lakes, NJ, USA). After incubation for 15 min at room temperature in the dark, the red blood cells (RBC) were lysed by adding 450 $\mu$L of FACS lysing solution to each test tube for another 15 min at room temperature in the dark. They were then analyzed using FACS Canto II (BD Bioscience) and Flowjo software v10 (Treestar, Ashland, OR, USA) and are presented as percentages. Flow cytometry gating strategy for CD56+ NK cells, helper T cells and cytotoxic T cells were defined as CD3-CD56+, CD3+CD4+ and CD3+CD8 lymphocytes, respectively as shown in Fig. 1.

Absolute cell counts of lymphocyte subsets were obtained using an automatic DxH 500 hematology analyzer (Sysmex Corp., Kobe, Japan). The analyzed CBC subsets consisted of white blood cells (WBC), RBC, hemoglobin, hematocrit, platelets, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), erythrocyte sedimentation rate (ESR), red cell distribution width (RDW), and platelet distribution width (PDW). Percentage analysis for granulocytes were composed of neutrophil, lymphocyte, monocyte, eosinophil, and basophil. Analyzed immunocytes were lymphocyte subset immunophenotypes, which were CD3, CD4, CD8 and CD56. CD4/CD8 was calculated by dividing CD4 by CD8. The percentage of cytotoxicity was calculated with following formula.

$$\%_{cytotoxicity} = \frac{\text{Experimental} - \text{Effector Spontaneous} - \text{Targer Spontaneous}}{\text{Target Maximun} - \text{Target Spontaneous}} \times 100$$

#### 2.3.2 Health physical fitness measures

The health-related physical fitness components included body composition, strength, muscle endurance, flexibility, and cardiopulmonary endurance through a graded exercise test (GXT). Firstly, the body composition was measured using a bioelectrical impedance analysis method with a body composition analyzer (Inbody 770, Biospace, Seoul, Korea). The variables of body composition in this study were height, body weight, muscle mass, fat mass, body mass index (BMI), fat percentage, and basal metabolic rate (BMR) [9]. Secondly, strength was measured using a grip strength test with a Smedley dynamometer. The participant held the dynamometer without touching any other part of the body. After both hands were alternately measured twice, the maximum value was recorded and the mean value from both hands were used. Thirdly, muscle endurance was measured using a sit-up test for 1 min. The participant lay

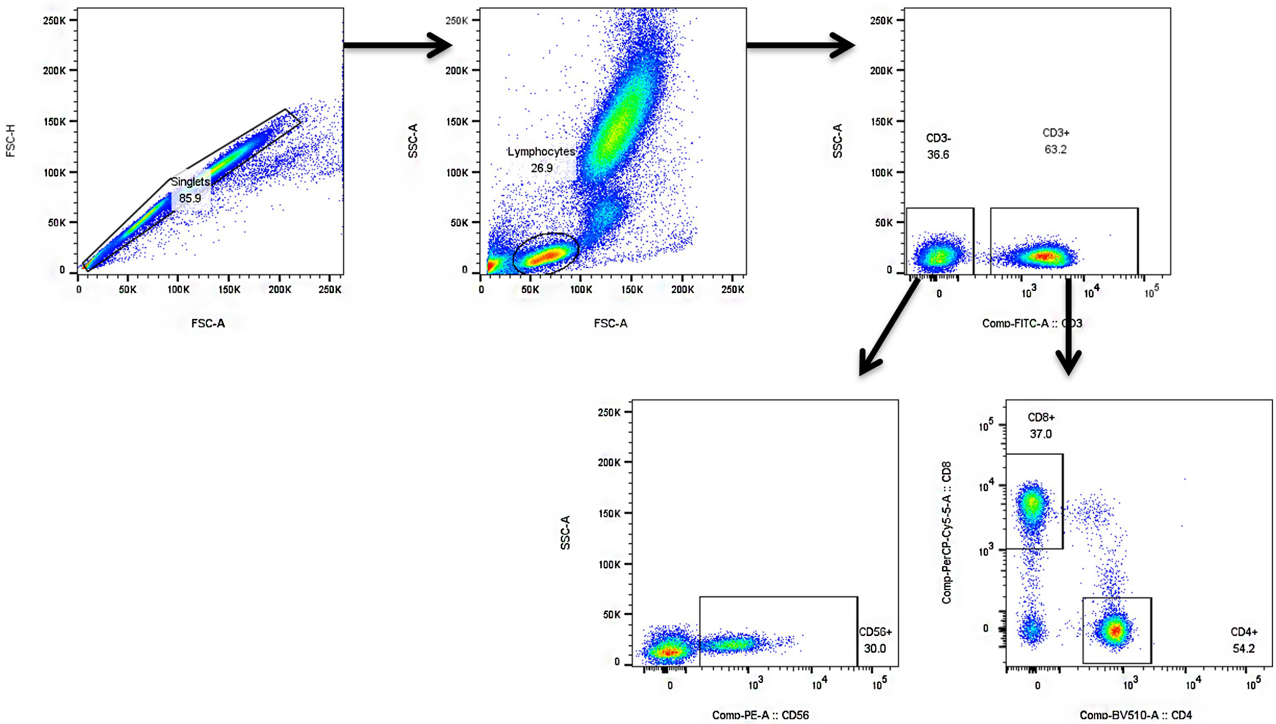


**Fig. 1. Flow cytometry gating strategy.** Singlet cells were gated by area and height of forward scatter.

down with his back on the floor, bended his knees at right angles, fixed his feet on the sit-up board, and placed his hands behind head with fingers interlocked. The total number of completed sit-ups was recorded. Fourthly, flexibility was measured using a sit and reach test that measured the degree to which the upper body bends forward in a sitting position with both legs fully outstretched. The participant took off his shoes and sat with his knees straightened before bending his upper body forward and extending his head toward the scale above a flexibility meter (TKK1859, Takei Inc., Tokyo, Japan). The maximum value of two measurements was recorded [10]. Lastly, this study assessed the maximal oxygen uptake ($VO_{2max}$) for cardiopulmonary endurance using a GXT. The devices used included an electrocardiogram (Q-4500, SunTech Medical Inc., Morrisville, NA, USA), automatic sphygmomanometer (M-412), gas tester (QMC4200), and treadmill (Q65 Series 90, Quinton Instrument Co., Seattle, WA, USA). The modified Bruce protocol was used for the participant who continued to walk or run until reaching an all-out level, which was his maximal RPE [11]. The $VO_{2max}$, resting heart rate, maximum heart rate, systolic blood pressure, and diastolic blood pressure were analyzed.

### 2.4 Exercise program

Elbow plank exercises were performed. Lying stretches were performed for 5 min before and after the plank exercise. During the workout phase, the participant maintained a straight and stable line from head to toes with no lowering of the hips while the shoulders and elbows were flexed at 90° as shown in Fig. 2.

The exercise intensity for the elbow plank exercise ranged from between "light" and "somewhat hard" (RPE 12) to "somewhat hard" and "hard" (RPE 14). A hand-sized copy of Borg's RPE chart was provided to the participant. The elbow plank exercise was conducted with the goal of reaching the exercise intensities mentioned above. A total of 30 min were divided into three 10-min stages, each with increased intensity. Specifically, it was performed until reaching RPE 12 in the first 10 min, RPE 13 in the second 10 min, and RPE 14 in the third 10 min. The same posture was maintained until reaching the target RPE for each stage. When the target RPE was reached, 1 min of rest was given before restarting.

### 2.5 Data analyses

Microsoft Excel 2019 (Microsoft, Redmond, WA, USA) was used to organize the data. SPSS (version 22.0; IBM Corp., Armonk, NY, USA) was used to perform all statistical analyses, and the Shapiro-Wilk test was used to check the data distribution. Differences between the weeks were observed using the Chi-square test. To observe changes before and after the elbow plank exercise, the delta percentage (%) was calculated using the formula of "((post data – pre data) $\div$ pre data) $\times$ 100" for all data. For all analyses, the significance level was set at $p \leq 0.05$.

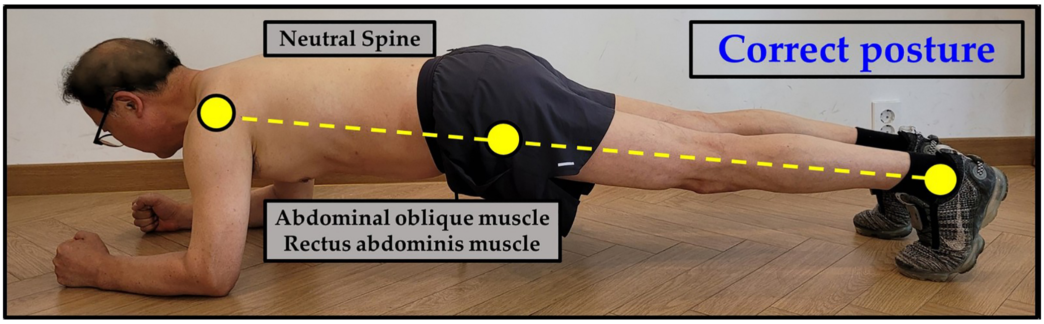


**Fig. 2. Correct elbow plank postures.**

**Table 1. Calorie intake and calorie out every week of the participant.**

| | Caloric intake | | | | Energy expenditure | | | |
|---|---|---|---|---|---|---|---|---|
| | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 |
| Mean | 1835.14 | 1830.71 | 1823.43 | 1880.29 | 310.14 | 290.57 | 315.57 | 311.29 |
| SD | 226.48 | 275.48 | 177.17 | 154.12 | 60.21 | 32.96 | 51.60 | 36.08 |
| $\chi^2$ | 0.001 | 0.714 | 0.001 | 0.714 | 0.857 | 0.001 | 0.001 | 0.714 |
| $p$ | 1.000 | 0.982 | 1.000 | 0.982 | 0.931 | 1.000 | 1.000 | 0.982 |

All values are expressed as mean ≤standard deviation. W, week; *p*-value was analyzed using the Chi-square test.

## 3. Results

### *3.1 Calorie intake and output for 4 weeks*

As shown in Table 1, the calorie intake levels were no significant differences among the seven days through 4 weeks. There were also no significant differences in the energy expenditure levels from Week 1 to Week 4.

### *3.2 Exercise time and rest time for 4 weeks*

On the first day of the experiment, the participant showed a high degree of enthusiasm in reaching the target RPE levels, but later learned the method and adopted a wave-like posture. As shown in Fig. 3, the average total exercise time performed was 20.73 min, whereas the average total rest time was 9.27 min.

### *3.3 Effect of elbow plank exercise on complete blood count*

As shown in Table 2, WBC of the subject was elevated before exercise, but showed a decreasing tendency after 4 weeks of plank exercise. However, RBC was not changed whereas, platelets somewhat increased. MCV, MCH, and MCHC decreased after 4 weeks. Meanwhile, although ESR (–50%) and PDW (–4.04%) decreased after 4 weeks of plank exercise, RDW% showed no changes in the participant.

### *3.4 Effect of elbow plank exercise on lymphocytes and granulocytes*

As shown in Table 3, neutrophils and monocytes decreased, while lymphocytes, eosinophils, and basophils increased after 4 weeks of elbow plank exercise. Meanwhile, CD3, CD4, and CD4/CD8 increased, while no changes were seen in CD8.

**Table 2. Changes of complete blood counts.**

| Items | Baseline | Week 4 | Delta % |
|---|---|---|---|
| WBC ($\times 10^3/\mu L$) | 10.7 | 8.8 | −17.76 |
| RBC ($\times 10^6/\mu L$) | 4.9 | 4.9 | 0.00 |
| Platelets ($\times 10^3/\mu L$) | 313 | 318 | 1.60 |
| MCV (fL) | 93.4 | 92.6 | −0.86 |
| MCH (pg) | 31.4 | 31 | −1.27 |
| MCHC (g/dL) | 33.6 | 33.3 | −0.89 |
| ESR (mm/hr) | 4 | 2 | −50.00 |
| RDW (%) | 13.2 | 13.2 | 0.00 |
| PDW (fL) | 9.9 | 9.5 | −4.04 |

All values are expressed as original data. WBC, white blood cell; RBC, red blood cell; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration; ESR, erythrocyte sedimentation rate; RDW, red cell distribution width; PDW, platelet distribution width.

As shown in Fig. 4, CD56 and cytotoxicity increased after 4 weeks. Specifically, CD56 was 10.1% before exercise, but increased to 13.8% after exercise, which was a 36.63% rate of increase. Meanwhile, the cytotoxicity promoted by NK cells was 23.1% before exercise and 24.88% after exercise, which was an increase of 7.71%. These results suggest that elbow plank exercises can help improve immunocyte function in an elderly man.

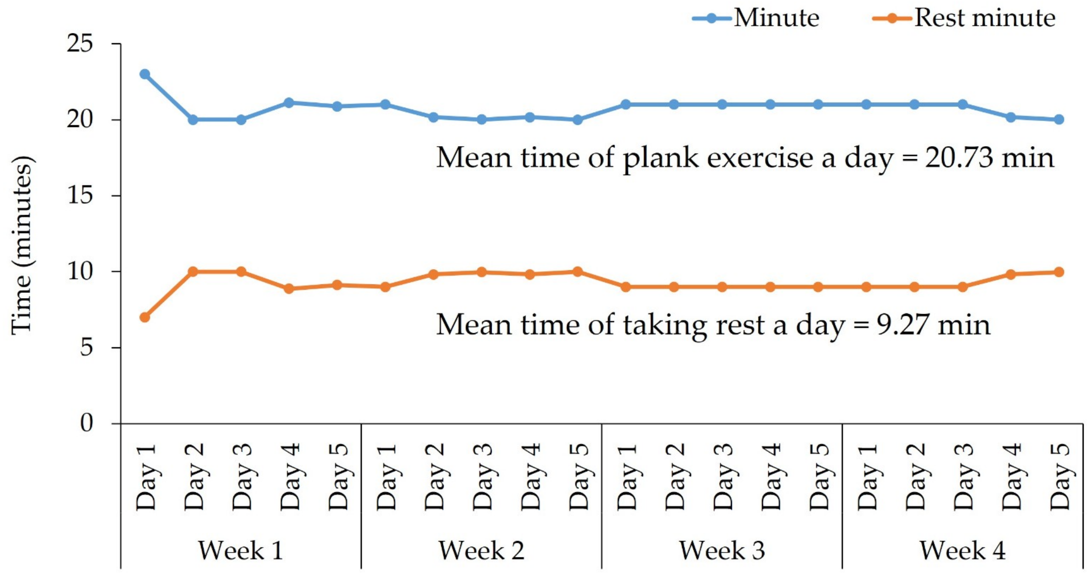


**Fig. 3. Total time of elbow plank exercise for 4 weeks.**

**Table 3. Changes in granulocytes and immunocytes.**

| Items | Baseline | Week 4 | Delta % |
|---|---|---|---|
| Neutrophil (%) | 43.9 | 38.2 | −12.98 |
| Lymphocyte (%) | 42.4 | 49.8 | 17.45 |
| Monocyte (%) | 11.3 | 9.1 | −19.47 |
| Eosinophil (%) | 2.1 | 2.4 | 14.29 |
| Basophil (%) | 0.3 | 0.5 | 66.67 |
| CD3 (%) | 46.9 | 49.6 | 5.76 |
| CD4 (%) | 36.1 | 39.2 | 8.59 |
| CD8 (%) | 10.8 | 10.8 | - |
| CD4/CD8 | 3.34 | 3.77 | 12.87 |

All values are expressed as original data. CD, cluster of differentiation.

**Table 4. Changes in body composition.**

| Items | Baseline | Week 4 | Delta % |
|---|---|---|---|
| Body weight (kg) | 66.2 | 65 | −1.81 |
| Skeletal muscle mass (kg) | 28.9 | 29 | 0.35 |
| Fat mass (kg) | 13.8 | 12.8 | −7.25 |
| Body mass index (kg/m$^2$) | 22.6 | 22.2 | −1.77 |
| Fat percentage (%) | 20.9 | 19.7 | −5.74 |
| Basal metabolism rate (kcal) | 1498 | 1501 | 0.20 |

**Table 5. Changes in cardiopulmonary fitness.**

| Items | Baseline | Week 4 | Delta % |
|---|---|---|---|
| $VO_{2max}$ (mL/kg/min) | 33.9 | 35.7 | 5.31 |
| Resting Heart Rate (beats/min) | 98 | 88 | −10.20 |
| Maximum Heart Rate (beats/min) | 157 | 159 | 1.27 |
| Systolic Blood Pressure (mmHg) | 125 | 114 | −8.80 |
| Diastolic Blood Pressure (mmHg) | 83 | 79 | −4.82 |

### *3.5 Effect of elbow plank exercise on body composition and physical fitness*

As shown in Table 4, body weight, fat mass, BMI, and fat percentage decreased, whereas skeletal muscle mass and BMR increased after 4 weeks. On the other hand, muscle strength was measured at 43.15 kg before starting the plank exercise and increased by 7.76% to 46.5 kg after completing 4 weeks as shown in Fig. 4. Muscular endurance was 31 reps/min at baseline, but increased by 29.03% to 40 reps/min at the end of experiment (Fig. 4). Flexibility was 1.5 cm before, and 3 cm after 4 weeks.

### *3.6 Effect of elbow plank exercise on cardiopulmonary fitness levels*

As shown in Table 5, $VO_{2max}$ and maximum heart rate increased after the plank exercises, while resting heart rate and resting systolic and diastolic blood pressure decreased in the elderly male participant after 4 weeks. It is known that plank exercise develops not only muscle function, but also cardiopulmonary function.

## 4. Discussion

This study found that 4-week elbow plank exercise caused various changes in CBC levels, as well as immunocyte functions in an elderly man. Characteristically, this study found that performing plank exercises decreased WBC, neutrophils, and monocytes. The participant in this study performed the elbow plank exercise at light to high levels of intensity. Since previous literature has stated that a moderate level of exercise intensity causes favorable changes in immunocyte function [12], it was recommended that the participant exercise at a somewhat higher level [13–18].

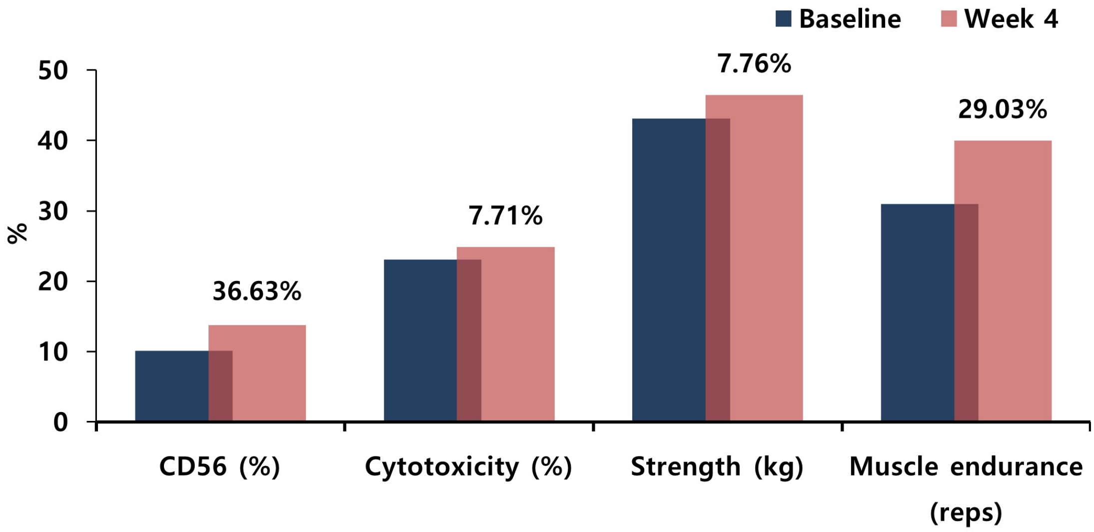


**Fig. 4. Changes of NK cell (CD56), cytotoxicity and physical fitness after 4 weeks.**

Chase *et al.* [19] reported that normative values for the plank exercise can be added to current fitness appraisal protocols to assess core muscular endurance. They suggested an average plank exercise duration of 1.58 min for females and 1.83 min for males. Moro-García *et al.* [20] reported that high volume exercises such as water rowing practice, running, and resistance training have been studied in athletes and non-athlete participants. The subjects they studied reported that the exercise was performed 6.2 ± 1 days a week with an average time of 125.3 ± 41.5 min per day. The total exercise time of the plank exercise in this study was 20.73 min a day, and the RPE was increased by 1 level every 10 min, with a target intensity of REP 14 for the final 10 min. In other words, the exercise time in this study was about 6 times shorter than that of Moro-García *et al.* [20]. However, it can be considered to have a higher exercise intensity. The effect of this exercise intensity can be even greater given the fact that the participant was an elderly person. Similar to the results of this study, Moro-García *et al.* [20] reported that high volume exercise significantly decreased the number of leukocytes, as well as the number and percentage of neutrophils and lymphocytes in young and elderly athletes. They also reported that no difference in T-cell receptor excision circles levels in CD4+ but not CD8+ T-cells of the younger individuals was examined. There was a reduction in the output of CD8+ T-cells from the thymus and in the distribution of subpopulations (CD4+ and/or CD8+ T-cells) [20]. This study also found that there was no change in CD8 whereas, the CD3, CD4, CD56, CD4/CD8, and cytotoxicity were increased. These results suggest that the progressive plank exercise can help improve the immunocyte functions of elderly people. As a result of this study, it was found that NK cells, including T cells involved in acquired immunity, increased. It was also found that the ability to remove foreign substances (CD4/CD8 and cytotoxicity) when infiltrating the human body also increased with a progressive intensity plank exercise.

Similarly, Moro-García *et al.* [20] reported that the levels of activation and degranulation of NK cells were significantly higher in young athletes than in young non-athletes. Carlson *et al.* [21] reported that other immunological cells including NK cells and cytokines were significantly increased. Evidence observed in previous studies suggest that yoga can strengthen the immune system. There was an increased level of CD4 and CD8 lymphocytes, B lymphocytes, and NK cells after practicing yoga compared to the control group [22]. According to Rajbhoj *et al.* [23], there were beneficial changes in the immune system, which led to a decrease in pro-inflammatory cytokines and an increase in anti-inflammatory cytokines in those who practiced yoga. The group which performed yoga had higher values of CD 4 and CD8 lymphocytes, B lymphocytes, and NK cells than the control group. There is evidence which proves that IL-10 is also increased in plasma level during yoga intervention [22,23]. Regarding immunocyte function in this study, neutrophils and monocytes decreased, while lymphocytes, eosinophils, and basophils increased after 4 weeks of elbow plank exercise. The total T cell (CD3), helper T cell (CD4), NK cell (CD56), CD4/CD8, and cytotoxicity increased. These results showed that performing elbow plank exercises changed the immunocyte function in an elderly man. In particular, when looking at the enhanced cytotoxicity related to NK cell functions, it seems that this plank exercise provided the participant protection from external substances. Recently, the COVID-19 pandemic has disrupted the lives of many people, resulting in mid- to long-term isolation. While it is necessary to follow social distancing protocols [2], exercise should continue at home.

This study observed positive changes in health-related physical fitness components through performing elbow plank exercises. Specifically, body weight, fat mass, BMI, and fat percentage of the participant decreased, whereas skeletal muscle mass and BMR increased after 4 weeks. Muscle strength, muscle endurance, and flexibility were increased by 7.76%, 29.03%, and 100%, respectively, after 4 weeks. This study also found that $VO_{2max}$ and maximum heart rate increased, while resting heart rate, systolic or diastolic blood pressure decreased after 4 weeks. It is known that plank exercise develops not only the function of peripheral tissues, but also the function of the cardiopulmonary system. Kim *et al*. [24] reported that isometric hip adduction during plank exercises could be a useful method to enhance abdominal muscle activity. Cortell-Tormo *et al*. [25] demonstrated the influence of the scapular and pelvic position on the EMG response of the core muscle groups and highlighted the greater contribution of these muscles to the postural stabilizing demanded during posterior pelvic tilt positions. Core exercises, such as the roll-out plank[26] and the suspended front plank [27], were also recommended for achieving high rectus abdominis activation [28]. The front plank with scapular adduction and posterior pelvic tilt, which belongs to the core stability exercise group, may be recommended for developing internal or external oblique activation. This isometric exercise showed the greatest activation values in the internal, perhaps due to the influence of the thoracolumbar fascia [25]. Core stability exercises have also been recommended for transversus abdominis activation [29]. The transversus abdominis is a primary trunk stabilizer, which modulates intra-abdominal pressure, the tension of the thoracolumbar fascia, and the compression of sacroiliac joints [30]. In addition to changes in various parts of the body through plank exercises stated in previous studies, this study found changes in overall physical strength after 4 weeks of plank exercises, which is a significant discovery.

A progressive exercise is followed by a decreased concentration of lymphocytes in the bloodstream, which results in low lymphocyte levels in tissues [31]. In light of these results, it can be inferred that the plank exercises performed in this study was maintained at light to high intensity for the participant. In the aspect of physical fitness, strength, muscle endurance, flexibility, and maximum oxygen uptake increased after 4 weeks. These results indicate that plank exercise can improve the health-related physical fitness components in elderly individuals and result in positive changes in NK cell-related functions. In other words, the results of this study showed that a progressive intensity of elbow plank exercise can increase the number of NK cells and improve its cytotoxicity. In this study, immunocytes, as well as health-related physical fitness components were measured one day before the start of plank exercises and on the day after completing the 4 weeks. As a result, a clear change was observed in the health-related physical fitness variables, and a constant change pattern was seen in the immune cells.

## 5. Conclusions

This study confirmed that plank exercises performed at light to high intensities improved immunocyte function and health-related physical fitness components in an elderly man. However, our study has some limitations. First, the sample size consisted of only an elderly man. Second, although there are hundreds of types of immunocytes, this study only observed a select portion of immunocytes. Considering these limitations, further studies that investigate the effectiveness of planks on a greater number of participants with diverse demographic backgrounds and on multiple immunocyte tests are encouraged.

## Abbreviations

WBC, white blood cell; RBC, red blood cell; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration; ESR, erythrocyte sedimentation rate; RDW, red cell distribution width; PDW, platelet distribution width.

## Author contributions

KSL and YSJ conceived the idea. KSL and GSH developed the background and performed the calibration of different devices used in the tests. SJH and SKP verified the methods section. All authors discussed the results and contributed to the final manuscript. KSL and JYC performed the tests. YSJ wrote the manuscript with support from SJH. All authors contributed to the final version of the manuscript. SKP and YSJ contributed to the interpretation of the results and data analysis, and they drafted the manuscript and designed the figures and tables. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

## Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Sahmyook University (2-1040781-AB-N-01-2017083HR). Prior to the study, the principal investigator gave a detailed explanation of the procedures to the participant, who read and signed an informed consent form.

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## Conflict of interest

The authors declare no conflict of interest.

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