Change in Neutrophil-to-Lymphocyte Ratio after acute and chronic exercise: A Systematic Review and Meta-Analysis

Running head: NLR change in exercise: A meta-analysis

Authors

Shokoufeh Khanzadeh[1], MD, Sanam Mohammadzadeh[2], MD, Farzad Fayedeh[3], Richard K. Shields[4], PT, PhD, FAPTA

1. Department of Physical Therapy and Rehabilitation Science, Carver College of Medicine, The University of Iowa, Iowa City, IA 52242, USA; shokoufeh-khanzadeh@uiowa.edu

2. Research Center for Evidence-Based Medicine, Iranian EBM Centre: A JBI Centre of Excellence, Tabriz University of Medical Sciences, Tabriz, Iran; sanam.mhm93@gmail.com

3. Student Research Committee, Birjand University of Medical Sciences, Birjand, Iran; FarzadFayedeh@gmail.com

4. Department of Physical Therapy and Rehabilitation Science, Carver College of Medicine, The University of Iowa, Iowa City, IA 52242, USA; richard-shields@uiowa.edu, ORCID: 0000-0002-5838-9317

* Correspondence richard-shields@uiowa.edu; Tel.: +1-319-335-9791; Fax: +1-319-335-9707; Address: 1-252 Medical Education Building (MEB), 500 Newton Rd, Iowa City, IA 52240, United States

Abstract

Background:

Chronic inflammation contributes to many common diseases, and exercise is a widely accessible tool to modulate it. This meta-analysis evaluates the neutrophil-to-lymphocyte ratio (NLR), a simple inflammatory marker, to better understand and optimize the anti-inflammatory effects of exercise. The present meta-analysis aims to systematically evaluate existing evidence on NLR changes induced by acute and chronic exercise.

Methods:

This study was registered in PROSPERO (CRD420251042422). Studies were selected based on PICO criteria: Population (P) – human participants regardless of age or health; Intervention (I) – acute or chronic exercise; Comparison (C) – NLR levels before exercise; Outcome (O) – Within-subject change in NLR measured before and after exercise. We searched PubMed, EMBASE, Scopus, Web of Science, and the Cochrane Library extensively. Pooled results were expressed as mean difference (MD) with 95% confidence intervals (CI) using STATA version 19.0.

Results:

Twenty-six studies with a total of 1203 participants were included. NLR levels showed no significant change immediately after acute exercise (MD = 0.03; 95% CI: –0.24 to 0.30; $p = 0.82$; $k = 12$, $I^2 = 93.6\%$) but increased significantly one-to-three hours post-exercise (MD = 1.23; 95% CI: 0.46 to 1.99; $p = 0.002$; $k = 5$, $I^2 = 93.3\%$). Chronic exercise was associated with a significant overall decrease in NLR (MD = –0.30; 95% CI: –0.56 to –0.04; $p = 0.02$; $k = 15$, $I^2 = 98.4\%$). Studies with older participants reported greater reductions in NLR following chronic exercise. Sensitivity analysis confirmed that no single study had a disproportionate influence on the pooled estimates, and publication bias tests did not suggest bias.

Conclusion:

Acute exercise induces a transient increase in NLR between one-to-three-hours post-exercise, while chronic exercise leads to sustained reductions, reinforcing the value of exercise as a non-pharmacologic strategy to reduce systemic inflammation, as reflected by this inflammatory marker.

New & Noteworthy

Neutrophil-to-lymphocyte ratio (NLR) was unchanged immediately after acute exercise but increased significantly by one to three hours later, reflecting a transient inflammatory response.

Chronic exercise leads to a significant reduction in NLR, indicating long-term anti-inflammatory benefits.

Studies with older participants reported greater reductions in NLR following chronic exercise.

Keywords

Meta-analysis; Neutrophil to lymphocyte ratio; Exercise; Inflammation

Introduction

Exercise has a major impact on the immune system, with effects that differ depending on intensity, duration, and frequency (1). Certain forms of acute exercise can elicit a transient inflammatory response, depending on the exercise modality, intensity, and individual characteristics. For example, recent meta-analysis found that exercise performed under both hypoxic and normoxic conditions led to an increase in IL-6 levels, while TNF-α elevation was observed only during hypoxic exercise (2). However, chronic training has been shown to provide anti-inflammatory advantages through many pathways, thereby holding considerable promise for the prevention and treatment of conditions associated with chronic inflammation (3-7). For example, a recent meta-analysis reported that, regardless of the type of training, exercise reduced circulating levels of several inflammatory and metabolic markers—including adiponectin, C-reactive protein (CRP), interleukins (IL-6, IL-18, IL-20), leptin, and tumor necrosis factor-α (TNF-α)—in individuals who were overweight or with obesity (4). Another meta-analysis suggested that in patients with type 2 diabetes, exercise reduces the level of inflammatory cytokines, including CRP, TNF-α, and IL-6 (5). Also, Sheldon et al. examined exercise-induced inflammatory and metabolic adaptations in older adults and found that aerobic training produced the greatest anti-inflammatory benefits, followed by resistance training(7).

These divergent responses between acute and chronic exercise highlight a complex pattern of immune modulation that may be effectively captured using integrated indicators like neutrophil to lymphocyte ratio (NLR)(8). Neutrophils, as part of the innate immune response, are among the first responders to exercise-induced stress or muscle damage, releasing enzymes and reactive species that promote inflammation (9). Lymphocytes, in contrast, mediate adaptive immunity and contribute to immune surveillance and recovery(10). The dynamic and often opposing behavior of these two cell types during and after exercise underpins the utility of the NLR, measured within the blood circulation, as a simple and integrative marker reflecting the balance between pro-inflammatory activation and immune regulation.

NLR is a widely accessible, simple, and sensitive biomarker of inflammation (11) and has been used and studied in a variety of disorders, including cancer, urinary tract infection, COVID-19 infection, stroke, and myocardial infarction (12-17). In contrast to commonly studied cytokines that require specialized laboratory techniques, NLR is easily calculated from standard hematological parameters, offering a cost-effective and widely accessible measure of systemic inflammatory status that may enhance translational applicability. Despite the presence of numerous original studies examining NLR modulation following acute or long-term exercise, no meta-analysis or systematic review has been conducted on this subject to date.

To address this gap, the present meta-analysis aims to systematically evaluate the existing evidence on the variations in NLR levels induced by acute and chronic exercise. By consolidating these findings, this study seeks to elucidate the role of NLR in exercise, offering insights into its potential as a predictive marker for recovery and advancing our understanding of the interplay between exercise, inflammation, and recovery processes. By elucidating the inflammatory profile associated with exercise, this work may provide a foundation for optimizing exercise prescriptions for people needing anti-inflammatory interventions.

2. Method

The protocol of the study was registered in PROSPERO (ID: CRD420251042422), and the completed PRISMA checklist is provided as **Supplementary tables S1 and S2**.

2.1. Search Strategy

We systematically searched PubMed, Embase, Web of Science, Cochrane, and Scopus for articles published before September 2, 2025. The search strategy was: ("exercise"[MeSH Terms] OR "exercise"[Title/Abstract] OR "Sport"[Title/Abstract] OR (("Physical"[All Fields] OR "high-intensity interval"[Title/Abstract] OR "weightlifting"[Title/Abstract] OR "Moderate-Intensity continuous"[Title/Abstract] OR "strength"[Title/Abstract] OR "aerobic"[Title/Abstract] OR "resistance"[Title/Abstract]) AND ("training"[Title/Abstract] OR "Program"[Title/Abstract]))) AND ("Neutrophil to lymphocyte ratio"[All Fields] OR "NLR"[All Fields]). No limitations regarding date or language were imposed. Reference lists of eligible studies were also screened. **Supplementary table S3** contains the complete search strategies for each database.

2.2. Study selection

Every article found through systematic searches of electronic databases was converted to the EndNote bibliographic and reference manager software. All duplicates were omitted. Two authors then independently reviewed the abstracts and titles, and potential studies were assessed for eligibility using predetermined criteria. Any disagreements were settled via discussion by the third author.

2.3. Eligibility Criteria

The PICO framework was used to define the inclusion criteria.:

- Population (P): Human participants of any age or health status, regardless of baseline physical activity level;
- Intervention (I): Acute or chronic exercise programs, with NLR assessed in peripheral human blood samples;
- Comparison (C): NLR levels of peripheral human blood measured before exercise compared to levels after exercise;
- Outcome (O): Within-subject change in NLR measured before and after exercise.

Exclusion criteria were as follows:

1. Non-peer-reviewed studies (e.g., conference abstracts), patents, or non-comparative studies (e.g., case series, case reports);
2. Non-quantitative studies (e.g., book chapters, commentaries, reviews, editorials);
3. Animal model studies;
4. Studies focusing on specific tissues (e.g., cerebrospinal fluid) rather than peripheral blood.

2.4. Data Extraction

For each included study, we extracted: first author, year, country, sample size, mean age, sex (% male), BMI, exercise type and duration (acute or chronic), health status (healthy vs. patient), exercise intensity, and NLR data pre- and post-exercise.

2.5. Risk of Bias Assessment

We assessed methodological quality using the National Institutes of Health (NIH) Quality

Assessment Tool for Before-After (Pre-Post) Studies Without Control Group, which includes 12 items on design, outcome reliability, adherence, and statistics(18). Each item was rated “Yes,” “No,” “Cannot determine,” or “Not reported.” Two reviewers independently evaluated all studies and reconciled inconsistencies through discussion.

2.6. Statistical Analysis

The statistical analysis was carried out using STATA version 19.0 (Stata Corporation, College Station, TX, USA). In studies where only graphical findings were presented rather than numerical data, we digitized the graphs and retrieved the data using WebPlotDigitizer Software. The reliability of WebPlotDigitizer has been previously validated (19). We imputed r = 0.7. The correlation coefficient (r) accounts for the within-subject relationship between pre- and post-intervention values(20-22). Overall mean difference (MD) in NLR values, along with the corresponding 95% confidence intervals (CIs), was reported. When the median and interquartile range were reported, we converted them to mean ± standard deviation (SD) using the method by Wan et al. (23). In addition, standard error (SE) was converted to SD using $SD = SE \times \sqrt{n}$
To further assess statistical heterogeneity among the studies, the Cochrane Q test ($\chi 2$) and the I^2 test were utilized (24). A random-effect model was then employed, with subgroup analysis based on participants' health status, exercise intensity, and quality of evidence, and meta-regression based on age, percentage of males, sample size, BMI, and exercise duration used to determine the source of heterogeneity. To categorize exercise severity for subgroup analysis, we used the authors’ own classification of exercise intensity. When studies did not report exercise intensity, we used the following definitions to determine exercise intensity(25):

1. High-intensity or severe exercise was defined as: (i) ≥77% of maximum heart rate (HRmax), (ii) ≥64% of VO_2max, (iii) Rating of Perceived Exertion (RPE) ≥ 14, or (iv) ≥70% of 1-repetition maximum (1RM) for resistance training.

2. Moderate-intensity exercise was defined as: (i) 64-76% of HRmax, 46-63% of VO_2max, or 50-69% of 1RM, 9ii) or RPE between 11–13.

Sensitivity analysis was conducted by a leave-one-out meta-analysis to illustrate the impact of each individual study on the overall estimate by sequentially excluding one study from the meta-analysis. In addition, GRADE (Grading of Recommendations Assessment, Development and Evaluation) method was used to assess the certainty of evidence(26). The funnel plot, Egger's test, and Begg's test were all used to investigate publication bias. A two-tailed $p < 0.05$ indicated statistical significance.

3. Result

3.1. Study Selection and Characteristics

The PRISMA flow diagram in **Figure 1** shows the selection process for studies included in this meta-analysis. Initially, 1885 records were identified. After removing duplicates, studies were screened in two steps: first by title/abstract, then by full-text review. Through this process, our meta-analysis includes 26 studies with 1203 participants in total. Among these, 12 studies assessed NLR changes immediately after acute exercise (27-38), with five of those also evaluating NLR changes one to three hours post-exercise (29, 30, 34-36). Fifteen studies focused on NLR changes after chronic exercise (29, 39-52). Among the acute exercise studies, 10 involved healthy participants (28, 30-38), and eight were rated as having high methodological quality (27, 29-34, 38). In chronic exercise group, 10 studies included participants with chronic disorders (29, 40, 42-44, 47-49, 51, 52), and 11 demonstrated high methodological quality (29, 39-45, 48, 51, 52). Additional details on the acute and chronic exercise studies are provided in **Tables 1 and 2**, respectively. In addition, **supplementary table S4** shows the quality assessment results of each included study using NIH tool.

3.2. Meta-analysis of the differences in NLR level before and immediately after acute exercise

Immediately after acute exercise, there was no significant change in NLR levels (MD = 0.03; 95% CI: -0.24 to 0.30; p = 0.82, **Figure 2**). Based on GRADE method, the certainty of evidence was downgraded to very low (**Supplementary table S5**). Substantial heterogeneity was present across studies ($I^2 = 93.6\%$, p for heterogeneity < 0.001), and a random-effects model was used.

For exercise intensity, studies assessing moderate exercise reported no effect on NLR (MD =0.10; 95% CI: –0.26 to 0.45; p = 0.59), while those evaluating vigorous exercise also showed no significant change (MD = –0.02; 95% CI: –0.35 to 0.32; p = 0.92). The between-group difference was not statistically significant (p = 0.65, **Figure S1**).

For participant health status, studies involving healthy individuals or athletes showed no effect (MD = 0.02; 95% CI: –0.26 to 0.29; p = 0.91), and those including patients with chronic disorders also reported no significant change (MD = 0.10; 95% CI: –0.34 to 0.55; p = 0.65). The between-group difference was not significant (p = 0.75, **Figure S2**).

For NIH quality assessment, studies rated as good (MD = –0.00; 95% CI: –0.38 to 0.38; p = 0.99) and those rated as fair (MD = 0.10; 95% CI: –0.24 to 0.45; p = 0.56) both showed null effects. The between-group difference was not statistically significant (p = 0.69, **Figure S3**). Overall, these factors did not explain the observed heterogeneity.

Meta-regression analyses revealed that none of the examined covariates—sample size (coefficient = 0.0023; p = 0.71), age (coefficient = -0.0041; p = 0.75), BMI (coefficient = -0.072; p = 0.43), or male percentage (coefficient = -0.0054; p = 0.38)—were significantly associated with the effect size. All models showed substantial residual heterogeneity (I^2 ranging from 79.7% to 94.1%), indicating that these variables did not explain the between-study variability. The adjusted R^2 values were near zero (ranging from –11.8% to 2.8%), suggesting no meaningful reduction in heterogeneity. These findings indicate that sample size, age, BMI, and sex distribution are unlikely to be major sources of heterogeneity in the effect of acute exercise on NLR.

3.3. Meta-analysis of the differences in NLR level before and one-to-three hours after acute exercise

The meta-analysis of five studies assessing NLR levels one-to-three hours after acute exercise demonstrated a statistically significant increase in NLR (MD = 1.23; 95% CI: 0.46 to 1.99; p = 0.002, **Figure 3**). Based on GRADE method, the certainty of evidence was downgraded to very low (**Supplementary table S5**). Substantial heterogeneity was present across studies (I^2 = 93.3%, p for heterogeneity < 0.001), and a random-effects model was applied.

For exercise intensity, moderate exercise was associated with a significant increase in NLR (MD = 1.10; 95% CI: 0.14 to 2.05; p = 0.02), whereas vigorous exercise showed a non-significant trend toward an increase (MD = 1.45; 95% CI: –0.11 to 3.01; p = 0.06). The between-group difference was not statistically significant (p = 0.71, **Figure S4**).

For participant health status, studies involving healthy individuals or athletes demonstrated a significant increase in NLR (MD = 1.18; 95% CI: 0.22 to 2.15; p = 0.01), while those including patients with chronic disorders did not (MD = 1.43; 95% CI: –0.38 to 3.24; p = 0.12). The between-group difference was not significant (p = 0.81, **Figure S5**).

For NIH quality assessment, studies rated as Good showed a significant increase in NLR (MD = 1.29; 95% CI: 0.40 to 2.17; p = 0.005), whereas studies rated as Fair did not (MD = 1.13; 95% CI: –0.85 to 3.11; p = 0.26). The between-group difference was not statistically significant (p = 0.89, **Figure S6**).

Meta-regression analyses revealed that none of the examined covariates—sample size (coefficient = 0.009; p = 0.87), age (coefficient = 0.026; p = 0.54), BMI (coefficient = –0.419; p = 0.35), or male percentage (coefficient = –0.015; p = 0.35)—were significantly associated with the effect size. All models showed substantial residual heterogeneity (I^2 ranging from 89.5% to 94.6%), indicating that these variables did not explain the between-study variability. The adjusted R^2 values were close to zero (ranging from –28.6% to 14.5%), suggesting no meaningful reduction in heterogeneity. These findings indicate that sample size, age, BMI, and sex distribution are unlikely to be major sources of heterogeneity in the effect of acute exercise on NLR.

3.4. Meta-analysis of changes in NLR following chronic exercise

The meta-analysis of 15 studies evaluating changes in NLR levels before and after chronic exercise showed a significant overall reduction in NLR (MD = –0.30; 95% CI: –0.56 to –0.04; p = 0.02, **Figure 4**). Based on GRADE method, the certainty of evidence was downgraded to low (**Supplementary table S5**). Substantial heterogeneity was observed across studies (I^2 = 98.4%, p for heterogeneity < 0.001), and a random-effects model was used.

When stratified by exercise intensity, moderate exercise was associated with a non-significant reduction in NLR (MD = –0.32; 95% CI: –0.73 to 0.09; p = 0.12), and severe exercise also showed a non-significant reduction (MD = –0.28; 95% CI: –0.62 to 0.06; p = 0.10). The between-group difference was not significant (p = 0.87, **Figure S7**).

For participants' health status, healthy individuals showed no significant change in NLR (MD = –0.03; 95% CI: –0.34 to 0.28; p = 0.83), whereas people with comorbidities demonstrated a significant reduction (MD = –0.47; 95% CI: –0.80 to –0.13; p = 0.006). The between-group difference was not statistically significant (p = 0.06, **Figure S8**).

In terms of NIH quality assessment, studies rated as good showed a significant reduction in NLR (MD = –0.44; 95% CI: –0.75 to –0.12; p = 0.007), whereas those rated as fair did not (MD = 0.01; 95% CI: –0.16 to 0.17; p = 0.93). The difference between subgroups was statistically significant (p = 0.01, **Figure S9**). These findings suggest that chronic exercise is generally associated with reductions in NLR, with stronger evidence observed in studies rated as higher quality.

Meta-regression analyses were conducted to explore potential sources of heterogeneity in the change in NLR following chronic exercise. Age was significantly associated with the effect size (coefficient = –0.017; 95% CI: –0.034 to –0.0004; p = 0.04), suggesting that studies with older participants tended to report greater reductions in NLR. In contrast, sample size (coefficient = –0.001; 95% CI: –0.005 to 0.002; p = 0.35), BMI (coefficient = –0.087; 95% CI: –0.209 to 0.035; p = 0.14), male percentage (coefficient = 0.0015; 95% CI: –0.006 to 0.009; p = 0.68), and exercise duration (coefficient = 0.027; 95% CI: –0.031 to 0.086; p = 0.33) were not significantly associated with effect size. Residual heterogeneity remained very high in all models (I^2 ranging from 95.17% to 98.49%), indicating that these covariates did not adequately explain the between-study variability.

3.5. Leave-one-out sensitivity analysis

As shown in **figure 5**, the leave-one-out sensitivity analysis revealed that no single study had a disproportionate influence on the overall effect size for changes in NLR following both acute and chronic exercise. These results suggest that the overall findings are stable and not driven by any single study.

3.6. Publication bias

Figure 6 presents funnel plots assessing potential publication bias among studies evaluating changes in NLR in response to exercise. For studies examining NLR immediately after acute exercise (**Figure 6A**), the funnel plot appeared largely symmetrical, and neither Egger's test (p = 0.41) nor Begg's test (p = 0.58) suggested evidence of publication bias. Similarly, for studies evaluating NLR one-to-three hours after acute exercise (**Figure 6B**), the funnel plot also appeared symmetrical, and neither Egger's test (p = 0.07) nor Begg's test (p = 0.25) indicated evidence of publication bias. Taking together, these results suggest that publication bias is unlikely to have substantially influenced the observed findings. Similarly, for studies evaluating changes in NLR after chronic exercise (**Figure 6C**), the funnel plot appeared symmetrical. Neither Egger's test (p = 0.78) nor Begg's test (p = 0.20) provided evidence of publication bias. Together with the results for acute exercise, these findings suggest that the observed effects are unlikely to be driven by small-study effects or selective publication.

4. Discussion

This meta-analysis explored the effect of exercise on NLR, a readily accessible marker of systemic inflammation and immune response. The results of our study highlight that NLR can function as a useful lens through which to understand how exercise influences inflammatory pathways, complementing evidence from cytokine studies and other immune markers. By reflecting the dynamic balance between neutrophils and lymphocytes, NLR provides a simple way to track how acute and chronic exercise modulates systemic inflammation.

4.1. NLR change immediately after acute exercise

No significant difference was observed in NLR levels immediately following acute exercise. This likely reflects the short time frame required for measurable systemic changes to occur after exercise. While immune processes such as neutrophil mobilization and cytokine release are initiated soon after physical activity, these responses may not yet be detectable in circulating blood counts in the immediate post-exercise window. Thus, the lack of change in NLR right after exercise may be due to the delay between the onset of immune activation and its measurable expression in peripheral blood.

4.1.1. Heterogeneity of results immediately after acute exercise

Considerable heterogeneity was observed in NLR responses immediately after acute exercise. We explored whether this variability could be explained by factors such as participants' health status, exercise intensity, study quality, age, sex distribution, sample size, or BMI, but none of these factors consistently accounted for the differences between studies. It is possible that unmeasured influences contributed to this heterogeneity, including other individual-level factors such as sleep quality, recent diet, hydration status, exercise training experience and starting fitness.

4.2. NLR change one-to-three hours after acute exercise

The second meta-analysis, including studies measuring NLR after one-to-three hours following acute exercise, demonstrated a statistically significant increase. This is consistent with a transient stress-induced immune response, increased neutrophils (53, 54), and relative lymphocytic suppression (55). In fact, the increased NLR reflects a physiological response to exercise-induced muscle stress and tissue repair processes, which require the engagement of innate immune components. These results emphasize the significance of sampling time when assessing post-exercise inflammatory markers. It has long been recognized that skeletal muscle inflammation is triggered by acute exercise. For example, in a study by Jiménez-Jiménez et al., eleven participants, ages 66 to 75, performed two eccentric exercise sessions separated by eight weeks of training. In peripheral blood mononuclear cells from older individuals, they found that acute eccentric exercise increases the expression of several genes associated with inflammation and the activation of nuclear factor Kappa B (NF-κB) immediately after and at 3 h after cessation of a bout of eccentric-damaging protocol (56).

4.2.2. *Heterogeneity of results one-to-three hours after acute exercise*

Subgroup analyses examined whether exercise intensity, participant health status, or study quality could explain the variability in the results. Although NLR increased significantly in some subgroups, such as in healthy participants, exercise with moderate intensity, or studies rated as good quality, other subgroups showed similar trends without reaching significance. However, the differences between these subgroups were not statistically meaningful, indicating that the apparent variation was not due to real group differences. In line with this, meta-regression based on age, sample size, sex distribution, and BMI also did not identify any significant sources of heterogeneity. The observed heterogeneity may stem from unaccounted individual-level factors, such as differences in the time frame of NLR measurement, sleep quality, recent dietary intake, hydration status, or baseline inflammatory condition.

4.3. Chronic exercise

In contrast to acute exercise, there was a significant overall decrease in NLR linked to chronic exercise. This supports the well-established anti-inflammatory benefits of long-term physical activity (57). Our findings that NLR decreases after long-term exercise are consistent with mechanistic studies demonstrating that regular training attenuates inflammatory signaling. For example, Jiménez-Jiménez et al. reported that although acute eccentric exercise enhanced NF-κB activation, and the expression of genes associated with inflammation in elderly individuals; these effects were significantly blunted following eight weeks of eccentric training. This supports the interpretation that chronic exercise reduces baseline inflammatory activity and enhances the body's ability to regulate immune responses(56).

4.3.2. Heterogeneity of results after chronic exercise

The observed variability in NLR responses to chronic exercise appears to be largely explained by differences in study quality and participant age, which emerged as major sources of heterogeneity across studies.

The subgroup analysis based on NIH quality ratings revealed that methodological rigor substantially influenced the observed effect of chronic exercise on NLR. Studies rated as good demonstrated a clear reduction in NLR, whereas those rated as fair showed no change. The statistically significant difference between these subgroups indicates that higher-quality designs tend to capture the anti-inflammatory effect of long-term exercise more consistently. This may reflect more standardized protocols and better control of confounding variables in well-conducted studies. Conversely, fair-quality studies—often with smaller sample sizes or incomplete reporting—may underestimate or obscure true biological changes due to greater measurement variability.

In addition, meta-regression identified age as a significant moderator. The negative coefficient suggests that studies with older participants reported greater reductions in NLR following chronic exercise. This pattern aligns with physiological expectations: older adults typically exhibit higher baseline systemic inflammation(58) and thus may experience a more pronounced normalization of immune balance with sustained exercise. Regular physical activity likely mitigates age-related immune-senescence and chronic low-grade inflammation ("inflammaging"), leading to larger measurable decreases in NLR in this subgroup(59).

The primary limitation of our meta-analysis is the high heterogeneity observed among the included studies. While the main sources of variability were identified in the chronic exercise analysis, particularly related to study quality and participant age, they could not fully explain the acute exercise results. To address this issue, we used a random-effects model to provide more robust and generalized estimates; however, some residual heterogeneity may still influence the pooled outcomes. In addition, the certainty of evidence was low for chronic exercise and very low for acute exercise according to the GRADE approach, primarily reflecting heterogeneity in study design, participant characteristics, and outcome assessment. These findings indicate that current evidence is limited and should be interpreted with caution.

In conclusion, our results emphasize the dynamic and time-dependent nature of immune responses to exercise. While acute exercise induces a transient increase in inflammatory markers after a delay, chronic exercise contributes to sustained reductions, supporting exercise as a practical approach to inflammation control.

Acknowledgments: Not applicable

Grant: This research received no external funding

Disclosures: The authors declare no conflicts of interest.

Author Contributions: Conceptualization, R.K.S.; methodology, Sh.Kh. and R.K.S.; statistical analysis, Sh.Kh.; data extraction, screening of articles, and quality assessment, Sh.Kh., S.M., and F.F.; writing—original draft preparation, Sh.Kh., S.M., and F.F.; writing—review and editing, R.K.S.; supervision, R.K.S.; All authors have read and agreed to the published version of the manuscript.

Abbreviations

IL: Interleukin

NLR: neutrophil to lymphocyte ratio

SE: standard error

SD: Standard deviation

MD: Mean difference

CI: 95% confidence interval

RCT: Randomized Controlled Trial

BMI: Body Mass Index

TNF-α: Tumor necrosis factor-alpha

PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses

MET: Metabolic equivalent of task

NIH: National Institutes of Health

CRP: C-reactive protein

nuclear factor Kappa B (NF-κB)

GRADE: Grading of Recommendations Assessment, Development and Evaluation

Supplementary Material: https://doi.org/10.6084/m9.figshare.31079284

References

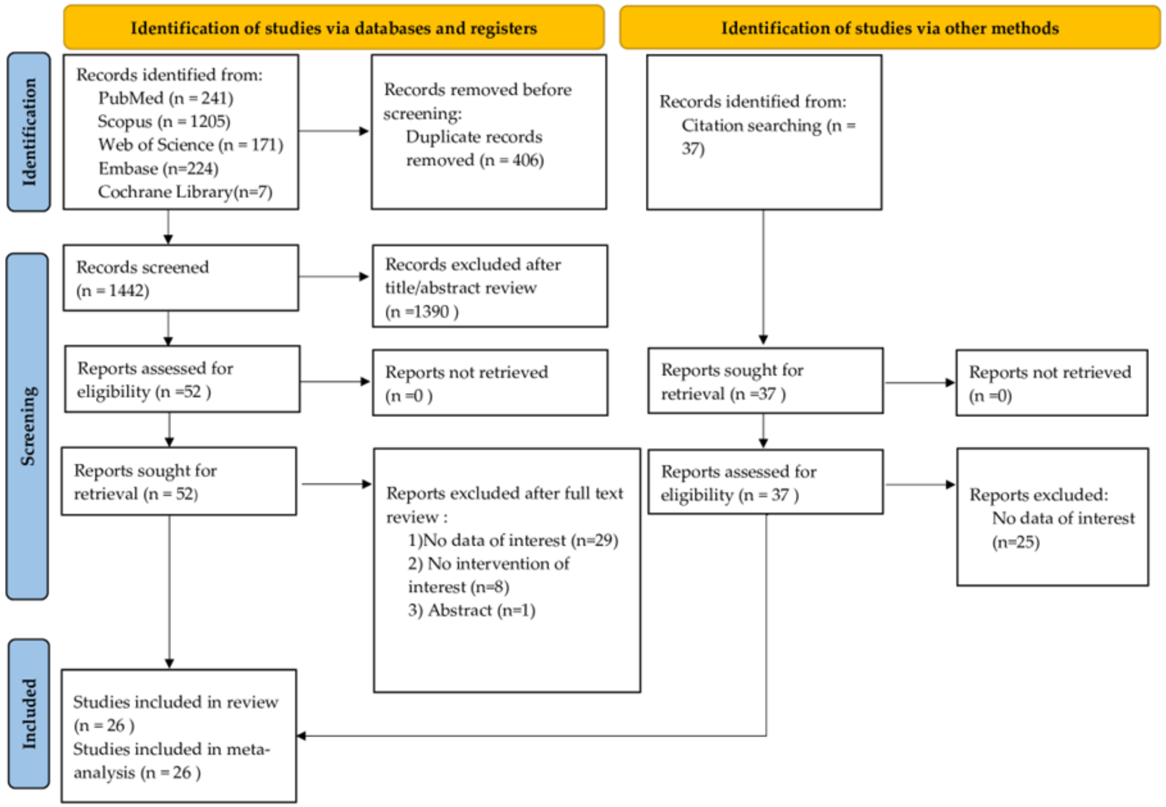
1. Koch AJ. Immune response to exercise. Brazilian Journal of Biomotricity. 2010;4(2):92-103.
2. Khalafi M, Sakhaei MH, Symonds ME, Noori Mofrad SR, Liu Y, Korivi M. Impact of exercise in hypoxia on inflammatory cytokines in adults: a systematic review and meta-analysis. Sports Medicine-Open. 2023;9(1):50.
3. Gleeson M, Bishop NC, Stensel DJ, Lindley MR, Mastana SS, Nimmo MA. The anti-inflammatory effects of exercise: mechanisms and implications for the prevention and treatment of disease. Nature reviews immunology. 2011;11(9):607-15.
4. Del Rosso S, Baraquet ML, Barale A, Defago MD, Tortosa F, Perovic NR, et al. Long-term effects of different exercise training modes on cytokines and adipokines in individuals with overweight/obesity and cardiometabolic diseases: A systematic review, meta-analysis, and meta-regression of randomized controlled trials. Obesity Reviews. 2023;24(6):e13564.
5. Chen X, Sun X, Wang C, He H. Effects of exercise on inflammatory cytokines in patients with type 2 diabetes: A meta-analysis of randomized controlled trials. Oxidative Medicine and Cellular Longevity. 2020;2020(1):6660557.
6. Khalafi M, Symonds ME, Faramarzi M, Sharifmoradi K, Maleki AH, Rosenkranz SK. The effects of exercise training on inflammatory markers in children and adolescents: a systematic review and meta-analysis. Physiology & Behavior. 2024;278:114524.
7. Sheldon MR, Gan MA, Tasong MJ, Yap A, Ahmad MM, Júnior PRH, et al. Exercise-induced inflammatory and metabolic adaptations in ageing: A meta-analytic compendium. Ageing Research Reviews. 2025:102974.
8. Zahorec R. Neutrophil-to-lymphocyte ratio, past, present and future perspectives. Bratisl Lek Listy. 2021;122(7):474-88.
9. Tidball JG. Inflammatory processes in muscle injury and repair. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology. 2005;288(2):R345-R53.
10. Nieman DC, Wentz LM. The compelling link between physical activity and the body's defense system. Journal of sport and health science. 2019;8(3):201-17.
11. Buonacera A, Stancanelli B, Colaci M, Malatino L. Neutrophil to lymphocyte ratio: an emerging marker of the relationships between the immune system and diseases. International journal of molecular sciences. 2022;23(7):3636.
12. Asik Z. The Role of the NLR and PLR in Urinary Tract Infection. Clinical Laboratory. 2021;67(10).
13. Sayed AA, Allam AA, Sayed AI, Alraey MA, Joseph MV. The use of neutrophil-to-lymphocyte ratio (NLR) as a marker for COVID-19 infection in Saudi Arabia: a case-control retrospective multicenter study. Saudi Medical Journal. 2021;42(4):370.
14. Howard R, Kanetsky PA, Egan KM. Exploring the prognostic value of the neutrophil-to-lymphocyte ratio in cancer. Scientific reports. 2019;9(1):19673.
15. Zhang S, Diao J, Qi C, Jin J, Li L, Gao X, et al. Predictive value of neutrophil to lymphocyte ratio in patients with acute ST segment elevation myocardial infarction after percutaneous coronary intervention: a meta-analysis. BMC cardiovascular disorders. 2018;18(1):75.

16. Yin Y, Wang J, Wang X, Gu L, Pei H, Kuai S, et al. Prognostic value of the neutrophil to lymphocyte ratio in lung cancer: A meta-analysis. Clinics. 2015;70:524-30.
17. Li W, Hou M, Ding Z, Liu X, Shao Y, Li X. Prognostic value of neutrophil-to-lymphocyte ratio in stroke: a systematic review and meta-analysis. Frontiers in Neurology. 2021;12:686983.
18. [Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.
19. Drevon D, Fursa SR, Malcolm AL. Intercoder reliability and validity of WebPlotDigitizer in extracting graphed data. Behavior modification. 2017;41(2):323-39.
20. Rosenthal R. Applied social research methods series, Vol. 6. Meta-analytic procedures for social research. Newbury Park, CA: Sage Publications; 1984.
21. Correia IR, Cardoso V, Cargaleiro C, Magalhães JP, Hetherington-Rauth M, Rosa GB, et al. Effects of home-based exercise programs on physical fitness in cancer patients undergoing active treatment: A systematic review and meta-analysis of randomized controlled trials. Journal of science and medicine in sport. 2023;26(4-5):222-31.
22. Silva FM, Duarte-Mendes P, Teixeira AM, Soares CM, Ferreira JP. The effects of combined exercise training on glucose metabolism and inflammatory markers in sedentary adults: a systematic review and meta-analysis. Scientific Reports. 2024;14(1):1936.
23. Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. BMC medical research methodology. 2014;14(1):135.
24. Cohen JF, Chalumeau M, Cohen R, Korevaar DA, Khoshnood B, Bossuyt PM. Cochran's Q test was useful to assess heterogeneity in likelihood ratios in studies of diagnostic accuracy. Journal of clinical epidemiology. 2015;68(3):299-306.
25. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, et al. Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise. Medicine & Science in Sports & Exercise. 2011;43(7):1334-59.
26. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, et al. GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. Journal of clinical epidemiology. 2011;64(4):383-94.
27. Korkmaz A, Yıldız A, Türker Duyuler P, Duyuler S, Yılmaz S, Basyigit F, et al. Combination of change in hematological parameters with exercise stress test to predict coronary artery disease. Journal of clinical laboratory analysis. 2018;32(1):e22205.
28. Kaniganti US, Majumdar P. Effect of a weight lifting training session on leukocyte count and myokine (Interleukin-6) levels. Journal of Physical Education and Sport. 2019;19(4):2435-40.
29. Joisten N, Proschinger S, Rademacher A, Schenk A, Bloch W, Warnke C, et al. High-intensity interval training reduces neutrophil-to-lymphocyte ratio in persons with multiple sclerosis during inpatient rehabilitation. Multiple Sclerosis Journal. 2021;27(7):1136-9.
30. Bańkowski S, Wójcik ZB, Grabara M, Ozner D, Pałka T, Stanek A, et al. Does curcumin supplementation affect inflammation, blood count and serum brain-derived neurotropic factor concentration in amateur long-distance runners? PloS one. 2025;20(1):e0317446.

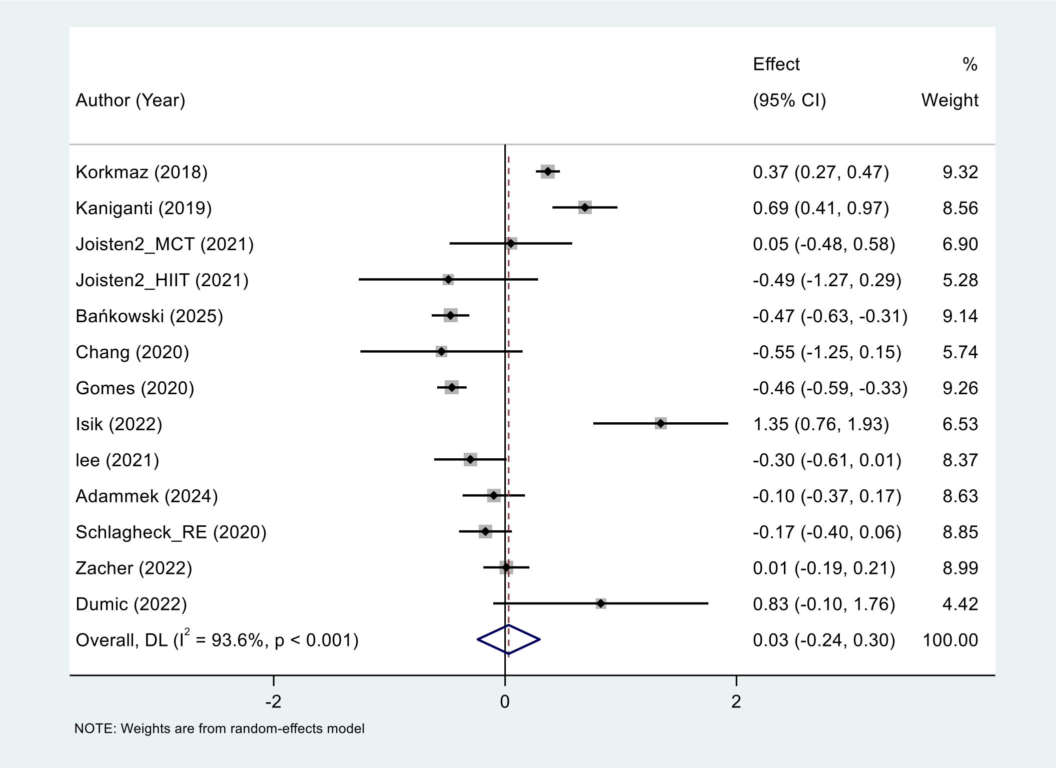
31. Chang W-G, Chen C-Y, Li W-F, Chou C-C, Liao Y-H. Traditional Chinese acupressure massage ameliorates systemic inflammatory responses and joint mobility limitation after acute repeated jumping exercise. Explore. 2020;16(1):26-34.
32. Gomes JH, Mendes RR, Franca CS, Da Silva-Grigoletto ME, Pereira da Silva DR, Antoniolli AR, et al. Acute leucocyte, muscle damage, and stress marker responses to high-intensity functional training. PloS one. 2020;15(12):e0243276.
33. Işık B, Küççüktürk S, Fatih Yüksel M, Boyalı E, Karaselek MA, Erdağı K. The effects of acute high intensity interval training on hematological parameters and neutrophils to lymphocytes ratio in elite taekwondo athletes according to gender. European Journal of Clinical and Experimental Medicine. 2022(3):306-15.
34. Lee M-C, Jhang W-L, Lee C-C, Kan N-W, Hsu Y-J, Ho C-S, et al. The effect of kefir supplementation on improving human endurance exercise performance and antifatigue. Metabolites. 2021;11(3):136.
35. Adammek F, Chirino TYW, Walzik D, Trebing S, Belen S, Renpening D, et al. Kinetics of immune cell mobilization during acute aerobic exercise in healthy adults. International Journal of Sports Medicine. 2024; 45(12): 908-916
36. Schlagheck ML, Walzik D, Joisten N, Koliamitra C, Hardt L, Metcalfe AJ, et al. Cellular immune response to acute exercise: Comparison of endurance and resistance exercise. European journal of haematology. 2020;105(1):75-84.
37. Zacher J, Wesemann F, Joisten N, Walzik D, Bloch W, Predel G. Cellular integrative immune markers in elite athletes. International Journal of Sports Medicine. 2023;44(04):298-308.
38. Dumić J, Cvetko A, Abramović I, Šupraha Goreta S, Perović A, Njire Bratičević M, et al. Changes in specific biomarkers indicate cardiac adaptive and anti-inflammatory response of repeated recreational SCUBA diving. Frontiers in cardiovascular medicine. 2022;9:855682.
39. Makras P, Koukoulis GN, Bourikas G, Papatheodorou G, Bedevis K, Menounos P, et al. Effect of 4 weeks of basic military training on peripheral blood leucocytes and urinary excretion of catecholamines and cortisol. Journal of sports sciences. 2005;23(8):825-34.
40. Rias YA, Kurniawan AL, Chang CW, Gordon CJ, Tsai HT. Synergistic effects of regular walking and alkaline electrolyzed water on decreasing inflammation and oxidative stress, and increasing quality of life in individuals with type 2 diabetes: A community based randomized controlled trial. Antioxidants. 2020;9(10):946.
41. Hadjicharalambous M, Chalari E, Zaras N. Influence of puberty stage in immune-inflammatory parameters in well-trained adolescent soccer-players, following 8-weeks of pre-seasonal preparation training. Exploration of Immunology. 2024;4(6):822-36.
42. Kaya BB, Özbilgin N. Effect of cardiac rehabilitation on mortality related inflammatory markers. Journal of Surgery and Medicine. 2019;3(8):588-92.
43. Mahmoud N, Mohammadreza HA, Abdolhosein TK, Mehdi N, Arent SM. Serum myokine levels after linear and flexible non-linear periodized resistance training in overweight sedentary women. European journal of sport science. 2022;22(4):658-68.
44. Malczynska-Sims P, Chalimoniuk M, Wronski Z, Marusiak J, Sulek A. High-intensity interval training modulates inflammatory response in Parkinson's disease. Aging Clinical and Experimental Research. 2022;34(9):2165-76.

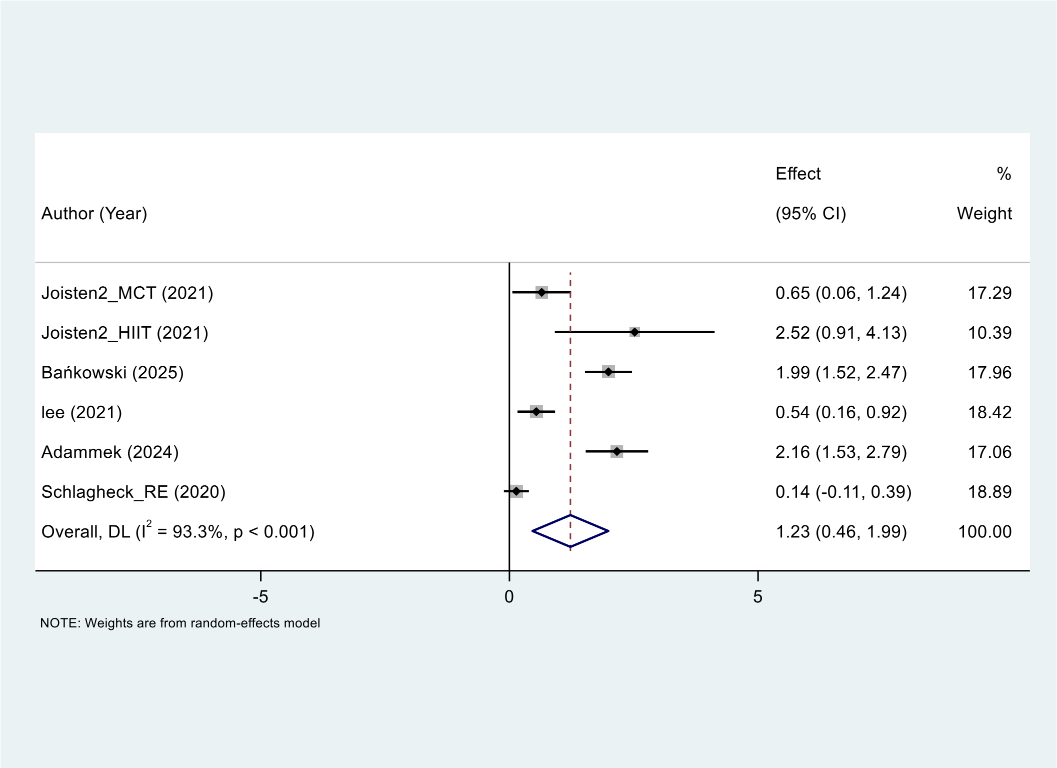
45. Mohamed AM, Shaaban EE, Mohamed EA, H Serry ZM. Lower-limb resistive versus aerobic training impact on quality of life in post-COVID-19 patients. Journal of Medicine in Scientific Research. 2021;4(4):12.
46. Nobari H, Cholewa JM, Pérez-Gómez J, Castillo-Rodríguez A. Effects of 14-weeks betaine supplementation on pro-inflammatory cytokines and hematology status in professional youth soccer players during a competition season: a double blind, randomized, placebo-controlled trial. Journal of the International Society of Sports Nutrition. 2021;18(1):42.
47. Pagola I, Morales JS, Alejo LB, Barcelo O, Montil M, Olivan J, et al. Concurrent exercise interventions in breast cancer survivors with cancer-related fatigue. International journal of sports medicine. 2020;41(11):790-7.
48. Poyraz E, Asarcıklı LD, Ozbilgin N. The effect of cardiac rehabilitation on inflammatory parameters in non-dipper hypertensive patients. Turkish Journal of Clinics and Laboratory. 2021;12(2):140-6.
49. Qian Z, Ping L, Dongming X, Xuelin Z. Slow-velocity eccentric-only resistance training improves symptoms of type 2 diabetic mellitus patients by regulating plasma MMP-2 and-9. Medicine. 2024;103(29):e38855.
50. Widasari N, Heriansyah T, Ridwan M, Munirwan H, Kurniawan FD. Correlation between high sensitivity C reactive protein (Hs-CRP) and neutrophil-to-lymphocyte ratio (NLR) with functional capacity in post COVID-19 syndrome patients. Narra J. 2023;3(2):e183.
51. Zengin İ, Arı S. Effect of cardiac rehabilitation on neutrophil-to-lymphocyte ratio and platelet-to-lymphocyte ratio in ST elevation myocardial infarction patients. The European Research Journal. 2019;5(6):1014-9.
52. Kara F, Özderya A, Uzun G, Kalaycioğlu E, Sayin MR, Turan T. The effect of exercise-based cardiac rehabilitation on neutrophil to lymphocyte ratio in patients with coronary artery disease. Cor Vasa. 2023;65(1):39-44.
53. Obeagu EI. Stress, neutrophils, and immunity: a dynamic interplay. Annals of Medicine and Surgery. 2025;87(6):3573-85.
54. Brown WM, Davison GW, McClean CM, Murphy MH. A systematic review of the acute effects of exercise on immune and inflammatory indices in untrained adults. Sports medicine-open. 2015;1(1):35.
55. Siedlik JA, Benedict SH, Landes EJ, Weir JP, Vardiman JP, Gallagher PM. Acute bouts of exercise induce a suppressive effect on lymphocyte proliferation in human subjects: a meta-analysis. Brain, behavior, and immunity. 2016;56:343-51.
56. Jiménez-Jiménez R, Cuevas MJ, Almar M, Lima E, García-López D, De Paz JA, et al. Eccentric training impairs NF-κB activation and over-expression of inflammation-related genes induced by acute eccentric exercise in the elderly. Mechanisms of ageing and development. 2008;129(6):313-21.
57. Langston PK, Sun Y, Ryback BA, Mueller AL, Spiegelman BM, Benoist C, et al. Regulatory T cells shield muscle mitochondria from interferon-γ–mediated damage to promote the beneficial effects of exercise. Science immunology. 2023;8(89):eadi5377.
58. Kale SS, Yende S. Effects of aging on inflammation and hemostasis through the continuum of critical illness. Aging and disease. 2011;2(6):501.

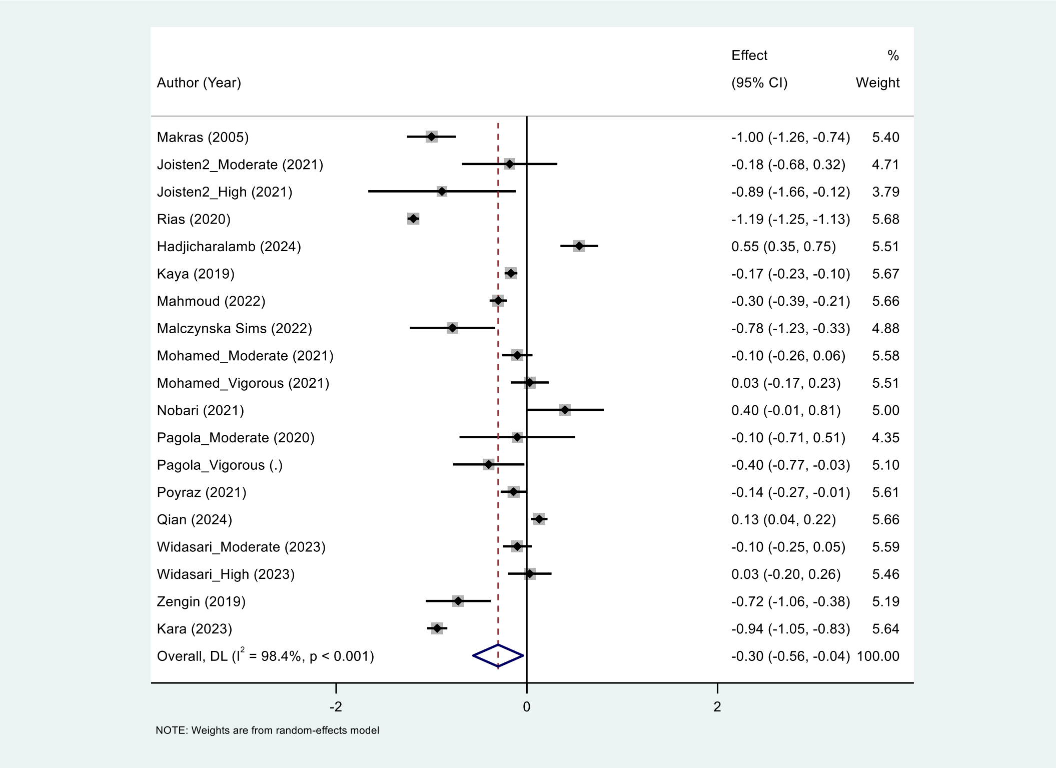
59. Domaszewska K, Boraczyński M, Tang Y-Y, Gronek J, Wochna K, Boraczyński T, et al. Protective effects of exercise become especially important for the aging immune system in the covid-19 era. Aging and disease. 2022;13(1):129.



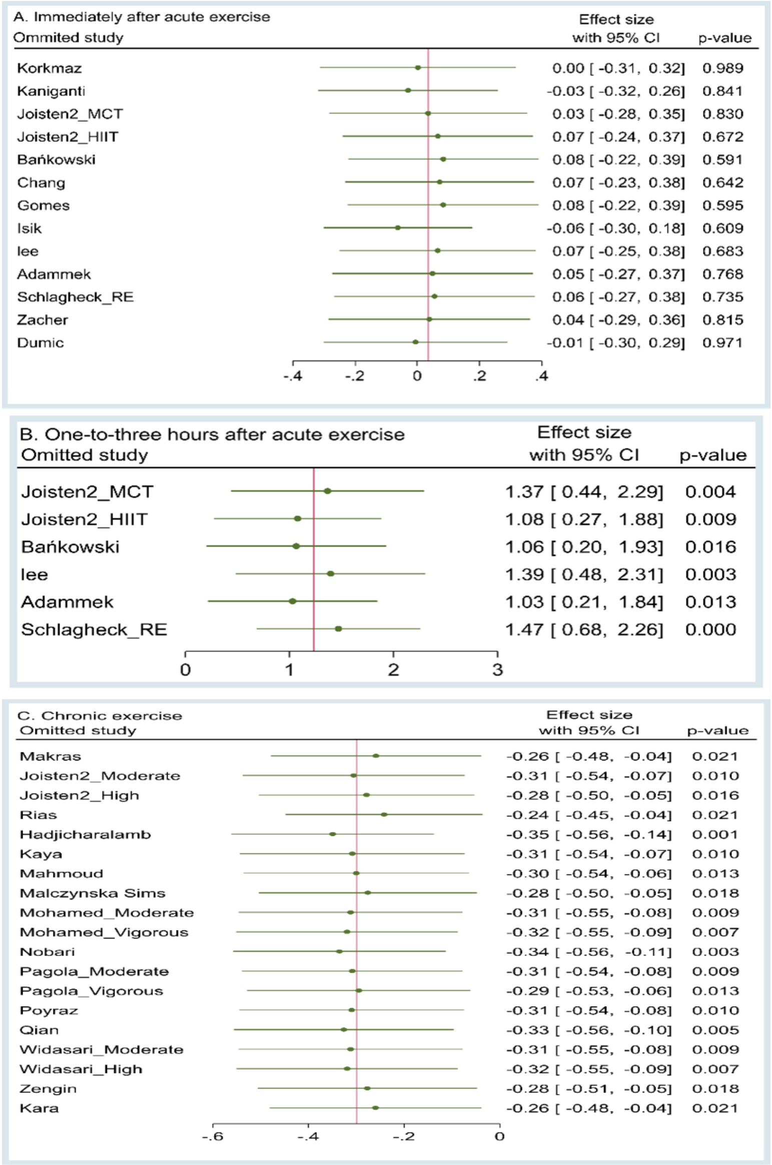
Identification of studies via databases and registers
Identification of studies via other methods
Identification
Screening
Included
Records identified from:
PubMed (n = 241)
Scopus (n = 1205)
Web of Science (n = 171)
Embase (n=224)
Cochrane Library(n=7)
Records removed before screening:
Duplicate records removed (n = 406)
Records identified from:
Citation searching (n = 37)
Records screened (n = 1442)
Records excluded after title/abstract review (n =1390)
Reports assessed for eligibility (n =52)
Reports not retrieved (n =0)
Reports sought for retrieval (n =37)
Reports not retrieved (n =0)
Reports sought for retrieval (n = 52)
Reports excluded after full text review :
1)No data of interest (n=29)
2) No intervention of interest (n=8)
3) Abstract (n=1)
Reports assessed for eligibility (n = 37)
Reports excluded:
No data of interest (n=25)
Studies included in review (n = 26)
Studies included in meta-analysis (n = 26)

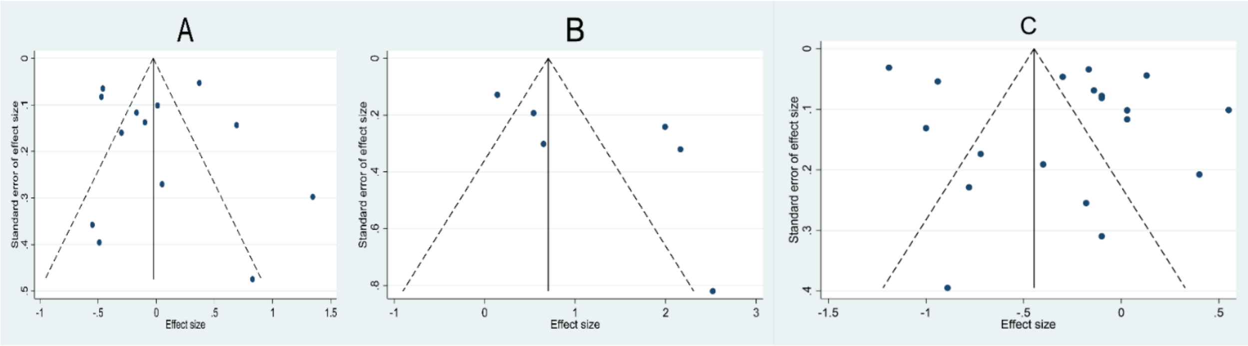

Author (Year)
Effect
(95% CI)
%
Weight
Korkmaz (2018)
0.37 (0.27, 0.47)
9.32
Kaniganti (2019)
0.69 (0.41, 0.97)
8.56
Joisten2_MCT (2021)
0.05 (-0.48, 0.58)
6.90
Joisten2_HIIT (2021)
-0.49 (-1.27, 0.29)
5.28
Bańkowski (2025)
-0.47 (-0.63, -0.31)
9.14
Chang (2020)
-0.55 (-1.25, 0.15)
5.74
Gomes (2020)
-0.46 (-0.59, -0.33)
9.26
Isik (2022)
1.35 (0.76, 1.93)
6.53
lee (2021)
-0.30 (-0.61, 0.01)
8.37
Adammek (2024)
-0.10 (-0.37, 0.17)
8.63
Schlagheck_RE (2020)
-0.17 (-0.40, 0.06)
8.85
Zacher (2022)
0.01 (-0.19, 0.21)
8.99
Dumic (2022)
0.83 (-0.10, 1.76)
4.42
Overall, DL (I² = 93.6%, p < 0.001)
0.03 (-0.24, 0.30)
100.00
-2
0
2
NOTE: Weights are from random-effects model


Effect
%
Author (Year)
(95% CI)
Weight
Joisten2_MCT (2021)
0.65 (0.06, 1.24)
17.29
Joisten2_HIIT (2021)
2.52 (0.91, 4.13)
10.39
Bańkowski (2025)
1.99 (1.52, 2.47)
17.96
lee (2021)
0.54 (0.16, 0.92)
18.42
Adammek (2024)
2.16 (1.53, 2.79)
17.06
Schlagheck_RE (2020)
0.14 (-0.11, 0.39)
18.89
Overall, DL (I² = 93.3%, p < 0.001)
1.23 (0.46, 1.99)
100.00
-5
0
5
NOTE: Weights are from random-effects model



Author (Year)
Effect
(95% CI)
%
Weight
Makras (2005) -1.00 (-1.26, -0.74) 5.40
Joisten2_Moderate (2021) -0.18 (-0.68, 0.32) 4.71
Joisten2_High (2021) -0.89 (-1.66, -0.12) 3.79
Rias (2020) -1.19 (-1.25, -1.13) 5.68
Hadjicharalamb (2024) 0.55 (0.35, 0.75) 5.51
Kaya (2019) -0.17 (-0.23, -0.10) 5.67
Mahmoud (2022) -0.30 (-0.39, -0.21) 5.66
Malczynska Sims (2022) -0.78 (-1.23, -0.33) 4.88
Mohamed_Moderate (2021) -0.10 (-0.26, 0.06) 5.58
Mohamed_Vigorous (2021) 0.03 (-0.17, 0.23) 5.51
Nobari (2021) 0.40 (-0.01, 0.81) 5.00
Pagola_Moderate (2020) -0.10 (-0.71, 0.51) 4.35
Pagola_Vigorous (.) -0.40 (-0.77, -0.03) 5.10
Poyraz (2021) -0.14 (-0.27, -0.01) 5.61
Qian (2024) 0.13 (0.04, 0.22) 5.66
Widasari_Moderate (2023) -0.10 (-0.25, 0.05) 5.59
Widasari_High (2023) 0.03 (-0.20, 0.26) 5.46
Zengin (2019) -0.72 (-1.06, -0.38) 5.19
Kara (2023) -0.94 (-1.05, -0.83) 5.64
Overall, DL (I² = 98.4%, p < 0.001) -0.30 (-0.56, -0.04) 100.00
-2
0
2
NOTE: Weights are from random-effects model


A. Immediately after acute exercise
Ommited study
Effect size with 95% CI
p-value
Korkmaz 0.00 [-0.31, 0.32] 0.989
Kaniganti -0.03 [-0.32, 0.26] 0.841
Joisten2_MCT 0.03 [-0.28, 0.35] 0.830
Joisten2_HIIT 0.07 [-0.24, 0.37] 0.672
Bańkowski 0.08 [-0.22, 0.39] 0.591
Chang 0.07 [-0.23, 0.38] 0.642
Gomes 0.08 [-0.22, 0.39] 0.595
Isik -0.06 [-0.30, 0.18] 0.609
lee 0.07 [-0.25, 0.38] 0.683
Adammek 0.05 [-0.27, 0.37] 0.768
Schlagheck_RE 0.06 [-0.27, 0.38] 0.735
Zacher 0.04 [-0.29, 0.36] 0.815
Dumic -0.01 [-0.30, 0.29] 0.971
-.4 -.2 0 .2 .4
B. One-to-three hours after acute exercise
Omitted study
Effect size with 95% CI
p-value
Joisten2_MCT 1.37 [0.44, 2.29] 0.004
Joisten2_HIIT 1.08 [0.27, 1.88] 0.009
Bańkowski 1.06 [0.20, 1.93] 0.016
lee 1.39 [0.48, 2.31] 0.003
Adammek 1.03 [0.21, 1.84] 0.013
Schlagheck_RE 1.47 [0.68, 2.26] 0.000
0 1 2 3
C. Chronic exercise
Omitted study
Effect size with 95% CI
p-value
Makras -0.26 [-0.48, -0.04] 0.021
Joisten2_Moderate -0.31 [-0.54, -0.07] 0.010
Joisten2_High -0.28 [-0.50, -0.05] 0.016
Rias -0.24 [-0.45, -0.04] 0.021
Hadjicharalamb -0.35 [-0.56, -0.14] 0.001
Kaya -0.31 [-0.54, -0.07] 0.010
Mahmoud -0.30 [-0.54, -0.06] 0.013
Malczynska Sims -0.28 [-0.50, -0.05] 0.018
Mohamed_Moderate -0.31 [-0.55, -0.08] 0.009
Mohamed_Vigorous -0.32 [-0.55, -0.09] 0.007
Nobari -0.34 [-0.56, -0.11] 0.003
Pagola_Moderate -0.31 [-0.54, -0.08] 0.009
Pagola_Vigorous -0.29 [-0.53, -0.06] 0.013
Poyraz -0.31 [-0.54, -0.08] 0.010
Qian -0.33 [-0.56, -0.10] 0.005
Widasari_Moderate -0.31 [-0.55, -0.08] 0.009
Widasari_High -0.32 [-0.55, -0.09] 0.007
Zengin -0.28 [-0.51, -0.05] 0.018
Kara -0.26 [-0.48, -0.04] 0.021
-.6 -.4 -.2 0


A
B
C
Standard error of effect size
Effect size

d studies in acute exercise analysis

ants	Mean age	BMI	Exercise type	Gender (Male %)	Sample Size	NLR level			Exercise protocol
						Pre-exercise	Immediately after exercise	One to three hours after exercise	
with y ms	57	-	Treadmill exercise testing	78%	113	2.04 ± 0.63	2.41 ± 0.78	-	Bruce protocol
l- ined ifters	19	-	Weightlifting training sessions (snatch, clean and jerk, and back squats)	38.46%	13	1.46 ± 0.64	2.15 ± 0.69	-	High-intensity weightlifting training sessions (75% relative intensity)
with e s	49.7	25.4	24 minutes Single bout of Moderate-Intensity continuous training on a bicycle ergometer	45.45%	33	3.18 ± 2.00	3.23 ± 2.01	After 3 hours: 3.83 ± 2.38	Moderate-intensity continuous training at 65% of their maximum heart rate
	50.9	25.3	5 × 1.5-minute intervals, Single bout of High-intensity interval	31.42%	35	3.80 ± 3.27	3.31 ± 2.15	After 3 hours: 6.32 ± 6.54	High-Intensity interval training at 95%–100% of their maximum heart rate

			training on a bicycle ergometer						
r aged e	38.33	23.85	Treadmill running test	100%	30	1.73 ± 0.61	1.26 ± 0.55	After 1 hour: 3.73 ± 1.68	A graded maximal treadmill running test with increasing speed/tilt until exhaustion
ı I nd- letes	21.35	21.55	Repeated vertical jumping exercises	100%	20	1.5 ± 2.16	0.95 ± 1.09	-	High intensity jumping exercises at a frequency of 0.7 Hertz (12 repetitions of 10 jumps; total of 120 jumps)
ional y nal oners	31	25.7	Single High-intensity functional training session, gymnastics, also known as the ‘Cindy’ workout	52.17%	23	1.26 ± 0.43	0.80 ± 0.25	-	Training consisted of completing as many rounds of 5 pull-ups, 10 push-ups, and 15 air squats as feasible within a 20-minute timeline
, elite ndo	20.5	21.12	90 minutes of unit training tailored to taekwondo, which includes a 50-minute high-intensity interval training component	50%	24	2.15 ± 1.11	3.50 ± 2.0	-	The range of training intensity was 80–90%

ed lthy	25.1	23.66	30 minutes of treadmill-based fixed-intensity trial	100%	16	2.06 ± 0.78	1.76 ± 0.86	After 1.5 hours: 2.60 ± 1.08	60% VO2max exercise challenge
	25.5	22.9	40-minute aerobic exercise on a bicycle Ergometer	50%	12	1.64+0.60	1.54+0.63	After 1 hour: 3.80+1.44	A moderate intensity of 60% VO2 peak was chosen
	24.6	25.4	Acute resistance exercise for 50 minutes	100%	24	1.99 ± 0.76	1.82 ± 0.71	After 1 hour: 2.13 ± 0.85	Exercise machine at 70% one repetition maximum
l c	16.1	20.3	Hallman-Venrath protocol on a standardized bicycle ergometer	44%	25	1.42 ± 0.56	1.43 ± 0.70	-	Maximal exercise test
ional	39.25	26.13	Recreational SCUBA dive at 20–30 meters depth, lasting 30 minutes each, in cold seawater conditions	100%	14	1.87 ± 0.70	2.70 ± 2.19	-	A dive was conducted to a maximum depth of 20 meters for a duration of 30 minutes, involving a steady descent to the maximum depth

									and a gradual rise to the surface without a decompression stop.

Body Mass Index; NIH, National Institutes of Health

d studies in chronic exercise analysis

nts	Sample size	Mean age (years)	BMI	Gender (Male%)	Exercise intervention/evaluation	NLR pre-exercise	NLR post-exercise	Exercise pr
young males military camp	48	21.3	23.2	100%	4 weeks 5x/week moderate intermittent mixed endurance exercise and resistance exercise	3.3 ± 1.25	2.3 ± 0.69	Gymnastic and climbin backpacks
with Sclerosis	33	49.7	25.4	45.45%	Moderate-intensity continuous training on a bicycle ergometer, 3 times per week for 3 weeks.	3.18 ± 2.00	3.00 ± 1.72	Moderate-i training at heart rate.
	35	50.9	25.3	31.42%	Training with high-intensity intervals on a bicycle ergometer, 3 times weekly for 3 weeks.	3.80 ± 3.27	2.91 ± 2.27	High-Inter 95%–100% heart rate.
nts with type s mellitus	20	54.70	-	35%	Regular walking for a duration of at least 30 minutes, five times/week for 8 weeks.	2.55 ± 0.18	1.36 ± 0.18	Walk aroun roads for a minutes/we

ned nt soccer	36	16.4	22.3	100%	8-week soccer-specific training 6 days/week, 8 friendly matches, and 48 training sessions. The sessions lasted between 60 and 90 minutes.	1.15 ± 0.35	1.70 ± 0.80	Soccer-spe training
nt patients of ac ation unit	211	56.28	-	46%	30 sessions of the tailored cardiac rehabilitation program in 10 weeks. Cycle ergometer training, strengthening exercises (after 2 weeks), and tailored adjustments every 10 sessions (based on Borg scale and progress).	1.70 ± 0.67	1.53 ± 0.60	Aerobic ex structured t muscle gro lower extre of the max repetitions
y, ght, non- sal women	19	Between 28 and 43	29.69	0%	linear or nonlinear periodized resistance training, 3 weekly training sessions for 12 weeks.	2.21 ± 0.27	1.91 ± 0.25	Resistance 60–90% of
ho have gnosed with n's disease	15	64.24	26.55	60%	12 weeks of High-Intensity Interval Training using a stationary cycloergometer. Three 1-hour training sessions were completed three times per week, for a total of 36 training sessions lasting 60 minutes.	2.58 ± 1.16	1.8 ± 0.5	High-Inten 60–80% of maximum
	30	Between 18 - 35		-	40-minute aerobic program using cycle ergometer	1.78 ± 0.6	1.68 ± 0.3	Aerobic pr week (on d

nd healthy th a past f COVID-19			less than 35		protocols, 6 weeks, 3 sessions/week.			moderate i peak heart
	30				Resistance training for the lower body using free weights (e.g., weightlifting, sand bags), 6 weeks, 3 sessions/week.	1.7 ± 0.78	1.73 ± 0.54	The resista initiated pr sessions, w set of exerc three sets a 70% of one
onal youth ayers	15	15.5	21.7	100%	Players participated in 4 training sessions and one match per week for 14 weeks.	1.5 ± 0.6	1.9 ± 1.1	All particip standardize on the intro heart rate d been report maximum
m breast urvivors who iously cancer- atigue at	10	51	27.3	0%	Unsupervised Aerobic training, instructed to complete ≥150 min/week moderate-vigorous physical activity, and less supervised resistance exercises for 16 weeks.	2.3 ± 0.6	2.2 ± 1.3	Moderate e training: ≥ moderate-v activity + R
	9	47	25.8		Supervised high-intensity aerobic (treadmill running, aerobic games, cycle-ergometer pedaling, or elliptical ergometer exercise) and Resistance exercises for 16 weeks.	2.0 ± 0.8	1.6 ± 0.6	High-inten very hard i resistance t

per sive patients.	58	56	26.30	44.8%	16-week supervised cardiac rehabilitation program (aerobic exercise on a cycle ergometer). Each session is 60 minutes, twice a week for the first 4 weeks, then three times a week for the next 12 weeks.	2.21 ± 0.69	2.07 ± 0.66	Moderate-i exercise pr maintained rating of 11 Scale.
with type 2 mellitus	22	-	24.76	-	Two weeks of pre-adaptation training followed by eight weeks of slow-velocity eccentric-only resistance training, conducted three times per week every other day for a duration of ten weeks.	1.38 ± 0.28	1.51 ± 0.25	Borg RPE between 11
healthcare with a history of moderate 19 infection	19	40.11	27.58	21.9%	Moderate intensity: Continuous aerobic exercise lasting 30 minutes every day, prescribed as treadmill walking for 6 weeks.	1.93 ± 0.47	1.83 ± 0.38	Three mile starting pac 69% of ma
	11	33.09	25.26	81.8%	30 minutes a day of interval high-intensity aerobic exercise, prescribed as running or jogging on a treadmill for 6 weeks.	1.74 ± 0.54	1.77 ± 0.41	Initiate wit to attain 70 heart rate.
with STEMI s, who	68	58.23	-	79.4%	8 weeks of cycling ergometry at least 1 month after primary PCI, for an average of 4 sessions	3.11 ± 1.95	2.39 ± 1.03	70-85% of

nt primary					weekly, each lasting 30 minutes.			
oronary sease ng exercise- rdiac ation	200	56.2	28.3	78%	Aerobic exercise on a cycle ergometer + muscle training before sessions for 5 days each week, totaling 6 weeks. Each session lasted 30 minutes.	2.64 ± 1.04	1.70 ± 0.55	Progressive 85% of ma reserve afte The RPE fo was 13–15

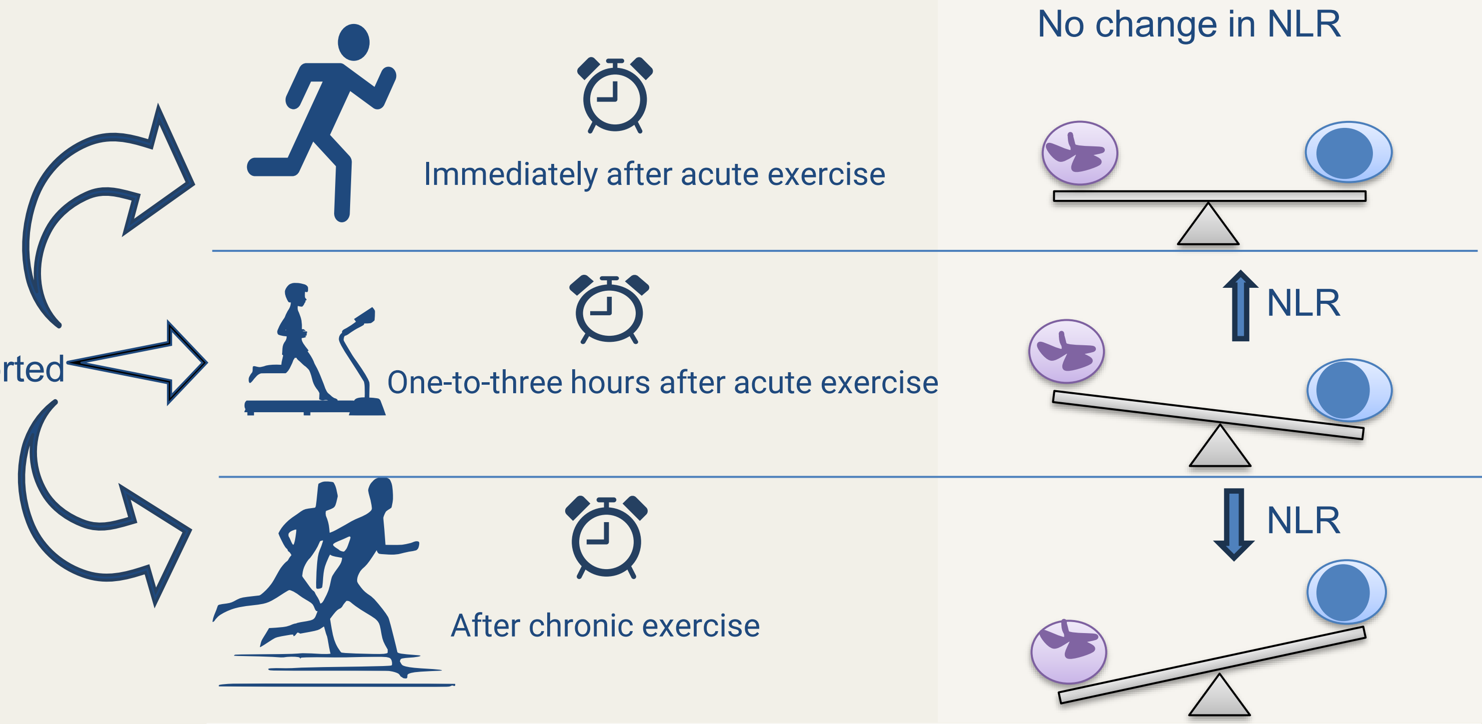
ex; NLR, Neutrophil to Lymphocyte Ratio; MET, Metabolic Equivalent of Task; STEMI, ST-segment elevation myocardial infar
h

Acute exercise increased and chronic exercise decreased Neutrophil-to-Lymphocyte Ratio

METHODS

Change in NLR was reported

OUTCOME



PROSPERO Code : CRD420251042422

Twenty-six studies involving a total of 1203 participants were included

CONCLUSION

While acute exercise induces a transient increase in NLR after a delay, chronic exercise contributes to sustained reduction, reinforcing its role as a non-pharmacologic strategy for inflammation control.