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Original Article

Adiponectin and Exercise: a Scientometric Analysis

Adiponectina y ejercicio: un análisis cienciométrico

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ABSTRACT

The objective of the present study is to analyze the field of application of Adiponectin, physical exercise, and their derivable aspects in healthy individuals and those with pathologies. The methodology used was developed based on an exploratory analysis of descriptive and inferential data, using the Science Tree algorithm for a field search within the Web of Science (WoS) and Scopus databases. Initial results indicate the existence of roots corresponding to classical topics in the field of Adiponectin and its relationship with insulin sensitivity, as it is a hormone that mitigates the spread of metabolic and cardiovascular diseases. The trunk refers to Adiponectin synthesis versus different types of exercise training, demonstrating a close relationship between physical exercise and Adiponectin depending on the type of training. The leaves represent three branches that bifurcate towards specific topics such as the relationships evident between Adiponectin and physical exercise, the optimization of physical exercise interventions to increase Adiponectin levels, and the physiological effects in the presence of exercise and diet in healthy individuals and those with underlying pathologies. It can be concluded that the total citation network contains highly relevant articles of interest to healthcare professionals. Future studies may indicate the need and interest in improving physical exercise interventions in association with other protective factors to increase Adiponectin levels in humans.

Keywords: adiponectin; exercise; obesity; insulin; bibliometrics; tree of science.

RESUMEN

El objetivo del presente estudio fue analizar el campo de aplicación de la adiponectina, el ejercicio físico y sus aspectos derivados en individuos sanos y aquellos con enfermedades. La metodología utilizada se desarrolló a partir de un análisis exploratorio de datos descriptivos e inferenciales, utilizando el algoritmo *Science Tree* para una búsqueda en el campo, dentro de las bases de datos Web of Science (WoS) y Scopus. Los resultados iniciales indican la existencia de raíces que corresponden a temas clásicos en el campo de la adiponectina y su relación con la sensibilidad a la insulina, ya que es una hormona que mitiga la propagación de enfermedades metabólicas y cardiovasculares. El tronco se refiere a la síntesis de la adiponectina frente a diferentes tipos de entrenamiento físico, lo que demostró una estrecha relación entre el ejercicio físico y la adiponectina, dependiendo del tipo de entrenamiento. Las hojas representan tres ramas que se bifurcan hacia temas específicos como las relaciones evidentes entre la adiponectina y el ejercicio físico; la optimización de las intervenciones de ejercicio físico para aumentar los niveles de adiponectina; y los efectos fisiológicos en presencia de ejercicio y dieta en individuos sanos y aquellos con enfermedades subyacentes. Se puede concluir que la red total de citas contiene artículos altamente relevantes, de interés para los profesionales de la salud. Los estudios futuros pueden indicar la necesidad e interés en mejorar las intervenciones del ejercicio físico en asociación con otros factores protectores para aumentar los niveles de adiponectina en humanos.

Palabras clave: adiponectina; ejercicio; obesidad; insulina; bibliometría; árbol de la ciencia.

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Introduction

Adiponectin is a hormone secreted by adipose tissue with anti-inflammatory properties linked to insulin sensitivity.[1] In this context, increasing or maintaining adiponectin concentrations in plasma could serve as a protective factor to counteract metabolic and cardiovascular diseases. One mechanism to augment this hormone is physical exercise; hence, various studies have sought to elucidate the relationship between adiponectin and physical exercise with the aim of understanding physiological mechanisms to maximize the efficacy and outcome of this association.[2,3] From this perspective, it has been suggested that the increase in adiponectin concentrations is achievable through the practice of physical exercise in different populations. However, other studies indicate that significant results are only observed with high-intensity exercises. This does not imply that light or moderate physical exercise does not have positive effects on people's health, but superior results that are maintained over time are evident with high intensity.

Physical exercise is framed as a protective practice for health, but the literature is ambiguous as to whether physical exercise alone increases adiponectin concentrations. Some studies have associated this practice with diet to enhance outcomes, but there are chronological gaps that provide clarity about the mechanisms by which adiponectin is modified in humans. Currently, systematic reviews[4] and meta-analyses[5,6,7] offer clarity about the functions of physical exercise on adiponectin in people with overweight/obesity and metabolic diseases. However, these reviews are framed in patients with underlying pathologies. While they conclude the benefits of physical exercise in relation to adiponectin, it is also necessary to consider it in healthy individuals. In that sense, the objective of this article is to analyze the field of application of Adiponectin, physical exercise, and their derivable aspects in healthy individuals and those with pathologies.

Methods

The output of the methodology was split into two sections: scientometric mapping and Tree of Science (ToS) from a search in Web of Science (WoS) and Scopus, following recent suggestions.[8,9] Table 1 showed the specific parameters in the search equation; for example, we used the words "adiponectin" and "exercise training" to identify relevant literature. Additionally, the merging process of the datasets was done using bibliometrix and tosr.[10]The results demonstrated the importance of taking into account both databases; for example, 407 (41.25%) documents were found in WoS but not in Scopus.

Table 1 - Parameters used in adiponectin and exercise training

Parameters	Web of Science	Scopus
Range	2000-2023	
Date	July 9, 2023	
Document types	Papers, books, chapters, and conference proceedings.	
Search field	Title, abstract, and keywords	
Words	“Adiponectin” AND (“exercise training”)	
Results	626	770
Total	1396	
Duplicates	407	
Total (Wos + Scopus)	989	

We showed the PRISMA flow chart adapted in figure 1 to represent the general procedure used to obtain and process the data. In the screening process, we applied text mining and web scraping techniques to split and disaggregate the data from the main file. This process generated an Excel file with cleaned data from references and integrated the Scimago Journal Ranking.

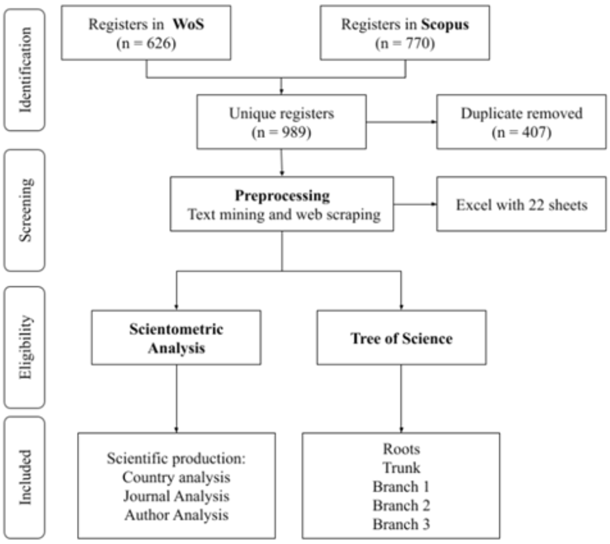

Fig. 1 – PRISMA flow chart adapted.

Scientometric Mapping

The scientometric mapping in this study is partitioned into three distinct segments. The initial segment elucidated the evolution of scientific production pertaining to adiponectin, contrasting the Web of Science (WoS) and Scopus databases and tracking their respective citation trajectories over time. The subsequent segment presented a country-specific analysis, employing three metrics: production volume, impact, and quality. The third segment highlights the most productive journals and their associated thematic groups. Ultimately, we scrutinized the collaboration network among researchers.

Tree of Science

The Tree of Science (ToS) recommended papers based on their importance in the citation network by applying the SAP algorithm.[11] The SAP algorithm acted as a metaphor for the sap process in plants, once the papers in roots, trunks, and leaves are identified, it starts to flow a metric from roots to leaves and then returned to the roots. In this vein, SAP algorithm improved the initially proposed algorithm.[12] ToS was been applied in different research topics such as engineering[9] and water governance.[13]

Results and Discussion

Scientific production

Next, a detailed analysis will be carried out on figure 2, which shows the total scientific production between adiponectin and physical exercise in two databases, WOS and Scopus. The figure provides an overview of annual production and citations from 2002 to the present. In this figure, a red line represents the total number of academic publications without duplicates, while a purple line indicates the annual citations received.

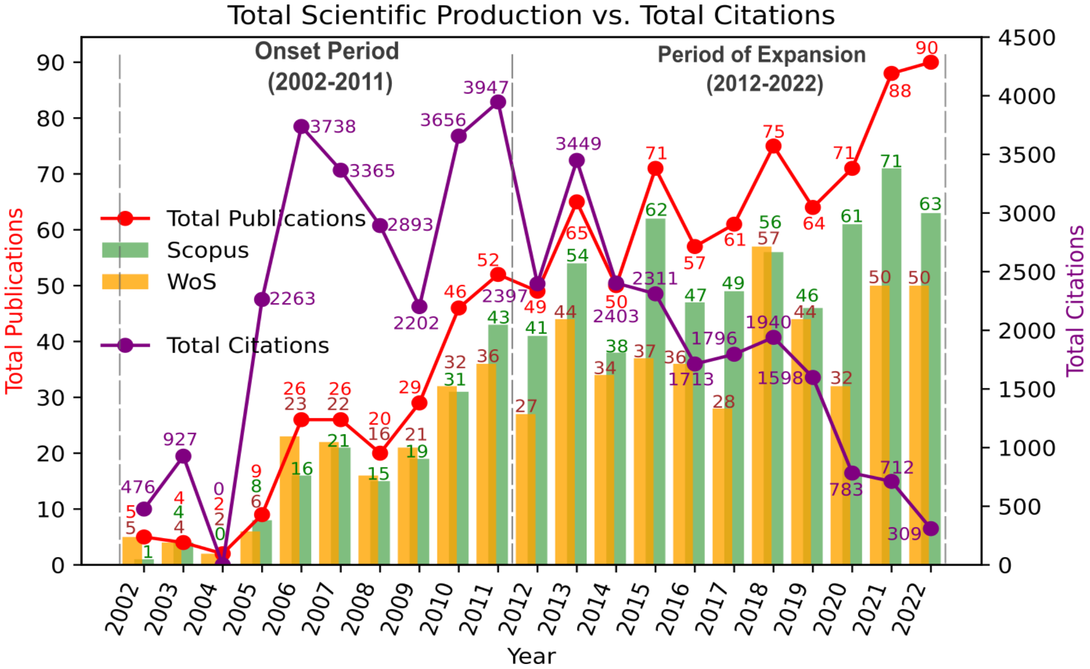

Fig. 2 – Annual Scientific Production of Adiponectin and Exercise.

Initiation Period

From 2002 to 2011, there is a positive growth (25.64%), which corresponds to the increase in scientific production of 219 articles. The growth of scientific production according to the linear trend R2 is 0.86, indicating a proportional increase between production and time in years. In the initial phase, scientific production has higher rates in the WOS database, except for the year 2011.

Finalization Period

From 2012 to 2022, there is also positive growth (6.27%), but it is lower compared to the previous period. This may be due to an ambivalent behavior with peaks and valleys. However, when analyzing the linear trend of the graph, the result is R2 = 0.65, indicating that the relationship between years and scientific production is not as strong compared to the previous period. Starting from the year 2011, publications are higher in Scopus, except for the year 2018. The highest peak of scientific production related to adiponectin and physical exercise occurs in the year 2022 (90 articles), while in 2020, the difference in the number of publications between WOS and Scopus is more relevant, with Scopus having a higher number.

Country Analysis

In this section, the scientific dynamics of countries are analyzed with respect to three variables: article production, impact measured by the number of citations received for all articles, and quality measured in quartiles according to the Scimago SJR and JCR classification (table 2).

Table 2 - Classification of scientific production of each country according to quartiles

Country	Production		Citation		Q1	Q2	Q3	Q4
USA	201	19.14%	9030	28.81%	134	34	11	0
Iran	108	10.29	936	2.99	18	22	24	29
Brazil	102	9.71	2048	6.53	46	32	9	1
Japan	60	5.71	1459	4.66	31	18	3	1
China	57	5.43	566	1.81	27	11	3	7
Italy	47	4.48	1679	5.36	20	17	2	1
Korea	43	4.1	968	3.09	19	10	3	3
France	41	3.9	1638	5.23	26	8	1	1
Australia	39	3.71	1105	3.53	24	8	2	0
Canada	35	3.33	1102	3.52	20	9	1	1

The country with the highest academic productivity in the field of adiponectin and physical exercise is the United States, with a total of 201 articles. Moreover, it also possesses the most highly cited articles, with a total of 9030 citations (28.81%). The most cited article in the United States is the work by authors *Nakamura MT*, *Yudell BE*, and *Loor JJ*,[14] who conduct a review on lipid metabolism, particularly focusing on long-chain fatty acids and the activation of alpha and delta peroxisome proliferation. Alpha peroxisomes induce beta-oxidation and ketogenesis to regulate low energy expenditure, while delta peroxisomes contribute to oxidation in combination with fasting and aerobic endurance exercise. This correlation is consistent since adiponectin is primarily synthesized in adipocytes, and exercise aims to decrease or mobilize triglycerides and low-density lipoprotein cholesterol.

In terms of impact, the United States (USA) holds the top position as it has been cited 9030 times (28.81%). When considering quality, USA also ranks first, with 134, 34, and 11 articles classified in the Q1, Q2, and Q3 categories, respectively (Scimago). It is worth noting that Iran has the second highest article production (108), but with a significantly low impact (2.99%), as the majority of scientific output from this country falls within the Q4 category of Scimago, comprising 29 articles (Table 2). Upon examining the trendline (R2) of the Q1, Q2, Q3, and Q4 quartiles for the top ten countries, we observe values of 0.34, 0.75, 0.52, and 0.16, respectively. Notably, the Q2 quartile is closer to 1, indicating a strong relationship among the ten countries within that quartile.

Regarding the relationship between authors from different countries and the affiliations of their researchers, the analysis reveals the formation of four groups of countries that form nodes with broad coverage. The first community is led by the United States (USA) and exhibits a close relationship between the United Kingdom and Germany. Interestingly, Iran shows a strong collaboration with the USA, with 26 joint efforts. One such collaboration is the work of *Hosseini* et al.,[15] which explores the effect of an interval training program on the plasma concentrations of lipocalin-2 and adiponectin in rats with induced myocardial infarction. These two adipokines are molecules that regulate inflammation and energy metabolism and are implicated in cardiovascular diseases. The study found that interval training increased levels of adiponectin, an anti-inflammatory and cardioprotective adipokine, but also elevated levels of lipocalin-2, a pro-inflammatory and atherogenic adipokine. These results suggest that interval training may have counterproductive effects on improving cardiac damage related to myocardial infarction.[15]

On the right side of figure 3, the number of countries within each community is displayed. Community one consists of approximately twenty countries, while community four only includes two countries (Portugal and Costa Rica). Interestingly, the Node and Link Figure over time shows a growth in the number of links relative to the percentage of nodes, indicating that the community of countries studying adiponectin has been consolidating over time.

Regarding the established communities shown in the figure, it is evident that in community three, France and Iran have the highest proportion of scientific production on the current topic. However, as mentioned earlier, Iran has a stronger collaboration with the USA, which leads community one. For instance, USA and Iran have collaborated in studies such as the effect of aerobic interval training on adipokines levels in women with multiple sclerosis and effects of exercise training on inflammatory and cardiometabolic health markers in overweight and obese adults.(16,17)

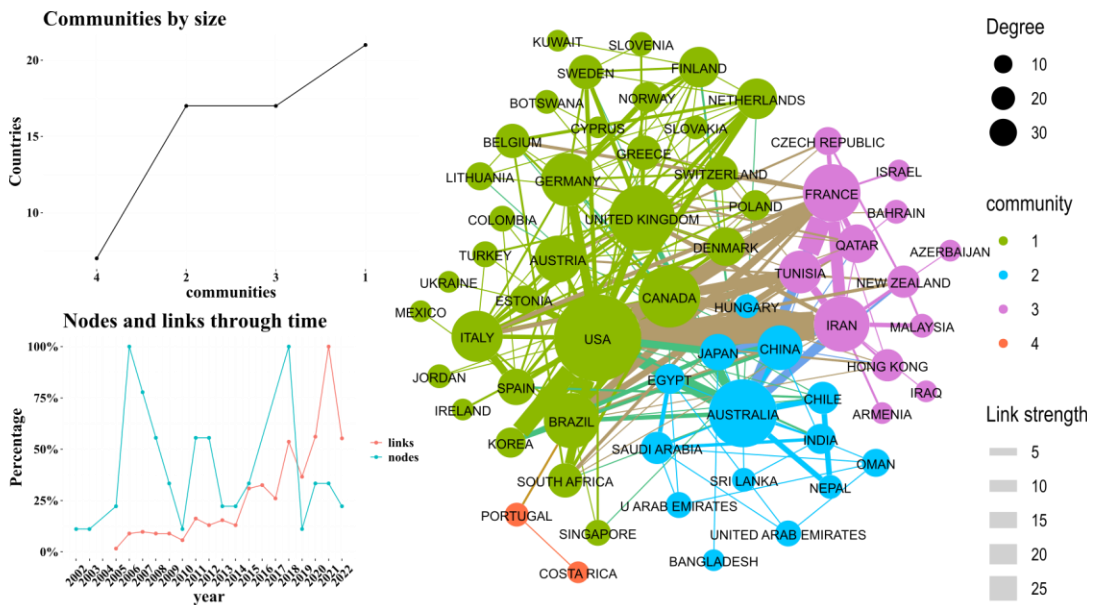

Fig. 3 – Scientific Collaboration among Countries.

Journal Analysis

Table 3 showcases the leading ten journals in terms of their academic productivity concerning adiponectin and exercise. Overall, it reveals the presence of six journals in the Q1 category, indicating that the articles pertaining to this subject possess a high level of quality, as classified by SJR y JCR. Additionally, it demonstrates a balanced distribution of scientific output across both the WoS and Scopus databases. Notably, the journal with the highest impact factor is Metabolism: Clinical and Experimental, which has published studies investigating the impact of exercise on insulin fluctuations.[18]

Table 3 - Top 10 journals of adiponectin and exercise

Journal	Wos	Scopus	Impact Factor	H index	Quantile
Medicine and Science in Sports and Exercise	26	19	1.73	251	Q1
Plos One	16	19	0.89	404	Q1
European Journal of Applied Physiology	20	15	0.88	151	Q1
International Journal of Environmental Research and Public Health	10	9	0.83	167	Q2
Metabolism: Clinical and Experimental	0	15	2.89	155	Q1
Nutrients	8	11	1.29	178	Q1
Frontiers in Physiology	10	9	01.03	140	Q1
Journal of Sports Medicine and Physical Fitness	12	9	0.5	74	Q2
Applied Physiology, Nutrition and Metabolism	0	11	0.86	102	Q2
Iranian Journal of Endocrinology and Metabolism	0	11	0.11	15	Q4

The journal with the highest number of articles is Medicine and Science in Sports and Exercise. This journal publishes articles related to sports medicine, epidemiology, and physiology.[19,20] The second journal with the most articles and the highest h-index is PLOS ONE, a more generalist journal but with specialized articles in the area of medicine and exercise.[21,22] In conclusion, the academic productivity surrounding adiponectin and exercise maintains high standards of quality, as evidenced by the caliber of the journals in which these articles are published.

Journal citation analysis facilitates the identification of the themes of a collection of papers; for instance, figure 4 depicts three clusters (groups) of papers revolving around a similar topic. Cluster 1 represents topics concerning obesity and exercise, such as the negative influence of exercise on the inflammation of certain tissues.[23] The second cluster focuses on circulatory problems.[16] The final cluster is more closely related to adiponectin and exercise in terms of endocrine effects.[24] The figure of nodes and links over time reflects the growth in the strength of the themes over time. There are increasingly more links in proportion to the nodes (journals), which allows for the observation of the consolidation of research around adiponectin and exercise.

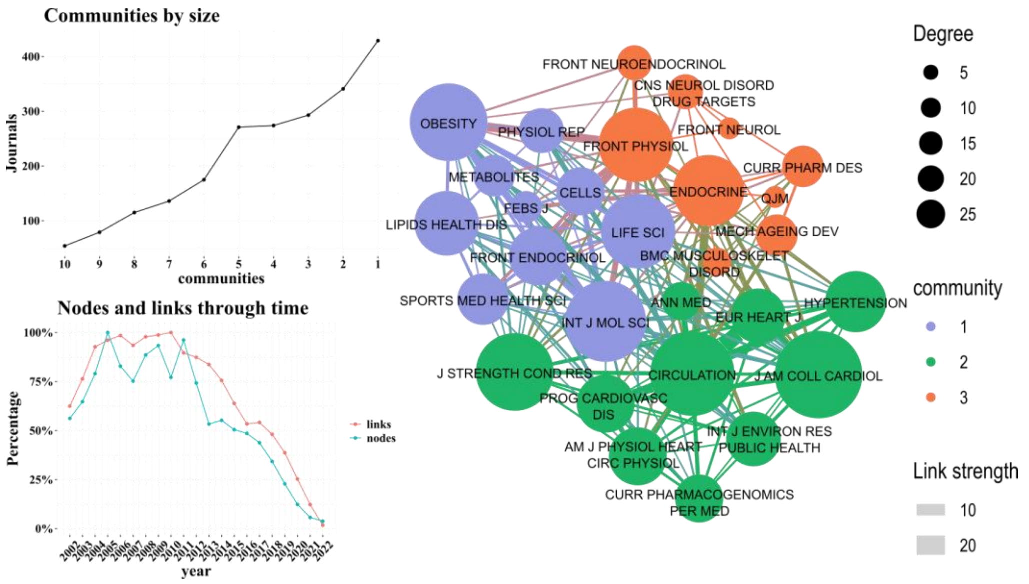

Fig. 4 – Citation network of journals in adiponectin and exercise.

Author Collaboration Network

Table 4 presents the ten authors with the highest academic productivity on adiponectin and exercise. Latin America has established itself as a global reference on this topic. For instance, Professor *Fábio Santos Lira* is renowned for his research within the framework of physical exercise from various perspectives, such as aerobic training, strength training, concurrent training, and its variability in response to potential scenarios faced by the population.(25,26)

Table 4 - Production of the top 10 authors in adiponectin and exercise

No.	Researcher	Total articles*	Scopsh-index	Affiliation
1	Lira F	13	39	Universidade Estadual Paulista "Júlio de Mesquita Filho", Sao Paulo, Brazil
2	Tabka Z	13	38	Faculty of Medicine Sousse, Sousse, Tunisia
3	Kirwan J	12	64	Pennington Biomedical Research Center, Baton Rouge, United States
4	Park K	12	2	Center for Sports Science in Gangwon, Chuncheon-si, South Korea
5	Tock L	12	24	Universidade Federal de São Paulo, Sao Paulo, Brasil
6	Tufik S	12	78	Universidade Federal de São Paulo, Sao Paulo, Brazil
7	Dâmaso A	11	32	Universidade Federal de São Paulo, Sao Paulo, Brazil
8	De M M	11	54	Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
9	Oyama L	11	37	Universidade Federal de São Paulo, Sao Paulo, Brasil
10	Kang S	10	13	Kangwon National University, Chuncheon, South Korea

Figure 5 illustrates the ego-networks (personal networks) of the researchers listed in table 1. The figure reveals four communities formed around the most productive researchers. The largest cluster comprises professors from the Universidade Federal de São Paulo, confirming the influence of geographical proximity in the formation of scientific teams.[12] An example of this is the collaborative work conducted by Professors *Lian Tock* and *Ana R. Dâmaso* on obesity in adolescents.[27]

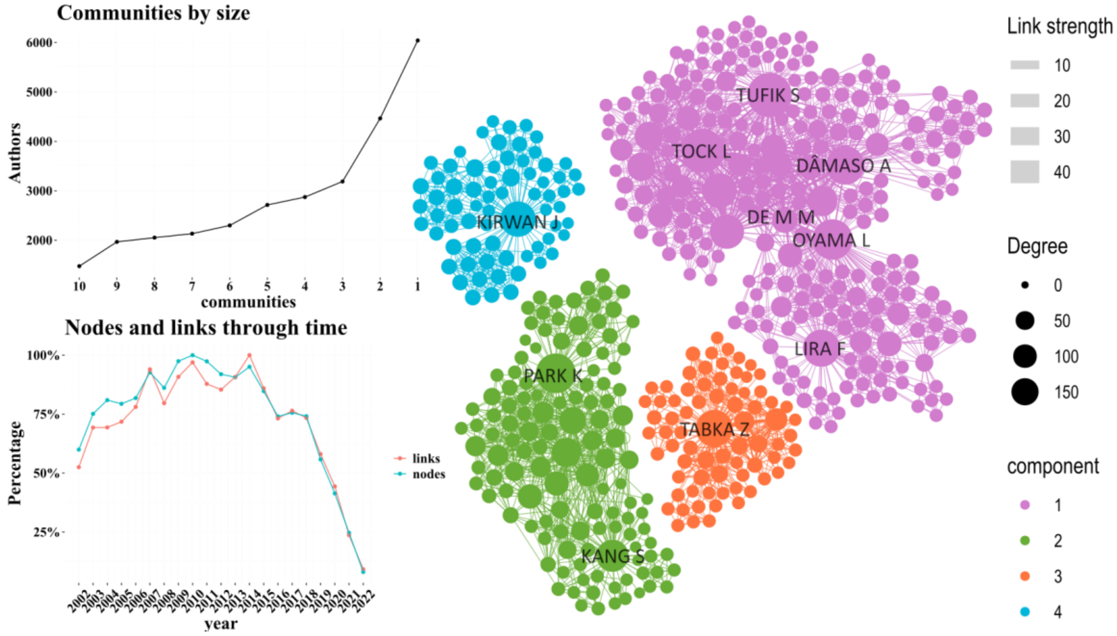

Fig. 5 – Personal social network of most productive researchers.

Tree of Science

Root

The "Homeostasis Model Assessment" (HOMA)[28] is a tool used to evaluate the relationship between fasting glucose and insulin. It quantifies insulin resistance, which occurs when the body's cells do not respond properly, leading to alterations in blood glucose levels, adipose tissue, and their association with Non-Communicable Chronic Diseases (NCDs). This indicates that adipose tissue is not simply a storage site but is considered an organ with endocrine, paracrine, and autocrine activity, influencing the body's metabolism. Adiponectin, a 244-amino acid hormone highly homologous to collagen VIII, X, and complement factor C1q, plays a role in this context.[29]

When analyzing adiponectin concentrations in patients with risk factors and physical exercise, it has been reported that patients with diabetes have low serum adiponectin levels.[30] However, some studies indicate that exercise may not modify this condition since adiponectin is not a contributing factor to exercise-related improvements in insulin sensitivity.[31] On the other hand, other studies suggest that 12-week exercise interventions in overweight and obese populations significantly increase insulin sensitivity and plasma adiponectin concentrations.[32,33] Nevertheless, the magnitude of effort translated into exercise intensity plays a crucial role in maintaining adiponectin levels over time, as other studies have found significant results with high-intensity exercises.[34,35] Apparently, there is no clear consensus regarding the role of physical exercise in relation to adiponectin concentrations, which prompted a systematic review on the effects of exercise on adiponectin levels. The review found that exercise with different prescriptions increases serum adiponectin levels, emphasizing the need for studies with a more robust design.[36]

Trunk (10)

The role of adiponectin as a biomarker is increasingly being investigated due to its clinical importance and potential therapeutic target. The synthesis of this adipocytokine is not exclusive to adipose tissue but also occurs in other systems, including the musculoskeletal system. Its significance is such that its potential therapeutic impact is being examined in muscular dystrophy, cognitive function, and other conditions.[37] Physiologically, adiponectin participates in muscle development, protein turnover, and the regulation of inflammatory signaling. The relationship between physical activity (quantity, quality/type) and the local and circulating isoforms of adiponectin (trimers, hexamers, HMW, and globular forms) remains unclear.[38]

Adiponectin regulates energy metabolism, and elevated levels are associated with cardioprotection and prevention of type II diabetes. Physical exercise increases circulating adiponectin levels in obese adults and patients with type 2 diabetes, with personalized training programs[39] or individualized exercise programs[40] being more effective. In this regard, High-Intensity Interval Training (HIIT) enhances substrate metabolism and insulin sensitivity. This effect may be attributed to the secretion of adiponectin-related proteins triggered by a single episode of HIIT.[41]

However, caution must be exercised to avoid fatigue as it can lead to chronic fatigue syndromes, overtraining, and potential damage to immune, endocrine, and inflammatory functions. Furthermore, oxidative stress increases under uncontrolled fatigue and negative energy balance. Therefore, oxidative stress and inflammation contribute to the reduction in serum adiponectin concentrations, which can have negative implications for health.[42]

When evaluating the isolated effect of strength training (ST) on lipid profile concentrations, C-reactive protein, and adiponectin in adults, it was found that this type of training stimulates an increase in HDL cholesterol and adiponectin concentrations and induces a decrease in triglyceride, total cholesterol, and LDL cholesterol levels. Therefore, ST training could be used as a therapeutic measure to improve inflammatory states and as a potential metabolic regulation in high-density lipoprotein synthesis.[43]

For example, the effects of moderate and intense exercise on inflammation and oxidative stress in athletes practicing basketball, swimming, soccer, and cycling showed an increase in adiponectin levels, possibly in response to reduced inflammation and muscle adaptation, which is a characteristic of effective training. These conditions can be altered by prolonged fatigue, overexertion, and training stress. Although athletes develop a good antioxidant defense system, oxidative stress can lead to a deterioration in athlete performance. In this regard, the use of redox markers becomes important among the indicators of appropriate training.[44]
As mentioned earlier, aerobic exercise is beneficial for reducing fat deposits. However, resistance exercise is associated with muscle preservation in children and adolescents with a body mass index greater than 25.[45] In overweight/obese

individuals, adipokine levels change according to acute or chronic physical activity (PA). However, the mode, intensity, duration, frequency, and type of physical exercise can alter the magnitude of the effect. Therefore, exercise modulates the complications of obesity, but the effectiveness of interventions directly related to adiponectin synthesis is still unknown.[46] In resistance training, adiponectin significantly increases compared to those who do not exercise.[47]

Figure 6 displays the citation network of adiponectin with the three main clusters (subareas). In the next section, we explain each subarea in detail.

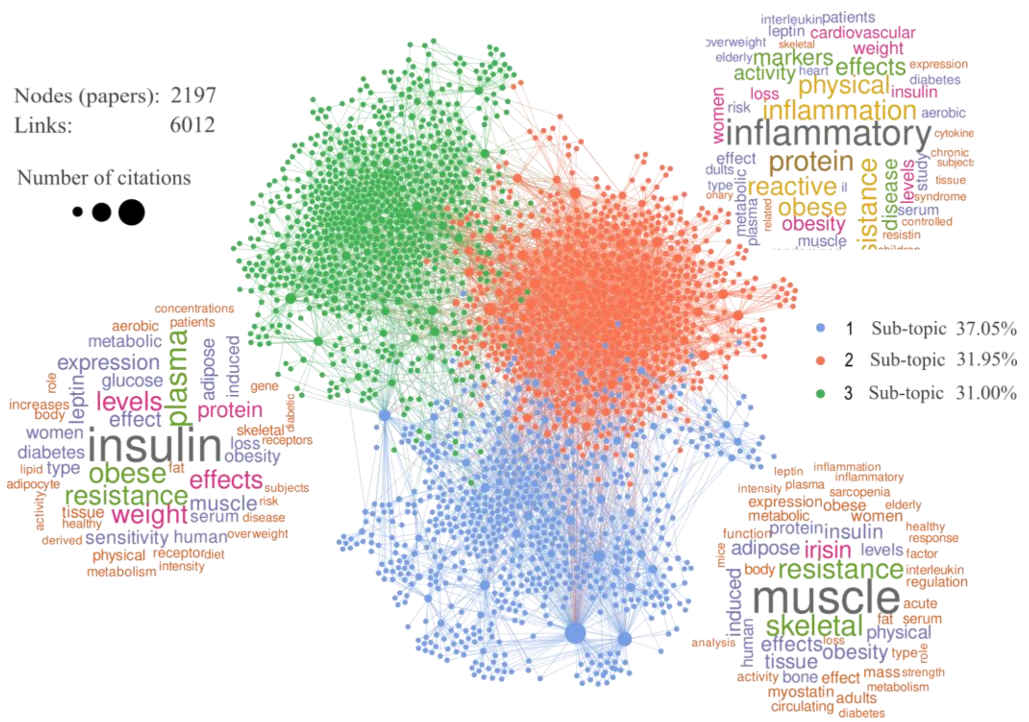

Fig. 6 – Citation network of adiponectin

Branch 1 - Relationships

In the initial domain, characteristics has been delineated based on existing modifications of glucose, insulin, and adiponectin concentrations resulting from physical exercise interventions in diverse populations. Elevated adiponectin concentrations are associated with a protective factor for health. Certain studies suggest that sedentary behavior is closely linked with triglycerides which in turn are negatively associated with adiponectin as well as visceral fat and insulin resistance.[48]

It is noteworthy that potential modifications can vary based on physical exercise, but these concentrations have shown differences according to the intensity of practice. In this case, investigations employing moderate-intensity physical exercise protocols discovered that it induces metabolic and anti-inflammatory improvements such as adiponectin, whether or not a non-communicable chronic disease is present.[49] A similar study with diabetic patients found analogous outcomes indicating an increment in adiponectin levels post-training.[50] Furthermore, high-intensity physical exercise shows more positive outcomes than moderate-intensity exercise. These improvements were found to be associated with low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), adiponectin, waist circumference, triglycerides (TG), and total cholesterol (CT) in obese women.[51] Now, this same intensity was used to intervene in adolescent students with attention deficit/hyperactivity disorder (ADHD), yielding outcomes similar to the previous study.[52]

From another perspective, physical exercise encompasses diverse intervention modalities. In the previous paragraph, findings based on intensities were observed; however, there exist physical training programs centered on aerobic resistance that relate to adiponectin. The increase in plasma adiponectin concentration is triggered by aerobic or anaerobic physical exercise practice, but after 30 days post-intervention, it reverts to its basal concentrations.[53]

In studies carried out in healthy rats, the effect of moderate and high-intensity physical exercise on adiponectin levels in fast and slow contraction muscles was investigated, concluding that no changes were observed in adiponectin levels at either of the two intensities.[54] A comparable study obtained results contrary to these; after six weeks of intervention in rats with breast cancer, an increase in adiponectin levels was found in all tissues except the tumor. Additionally, tumor growth decreased and muscular resistance increased.[55]

Branch 2-Optimization

In the domain of optimization, research endeavors have been implemented that apply physical exercise protocols with the intent to optimize modifications in adiponectin levels among populations with overweight/obesity conditions and metabolic and cardiovascular diseases. Within this context, a study was carried out with the aim of scrutinizing the long-term exercise effects on adiponectin and other inflammatory adipokines in patients afflicted with Type 2 diabetes and coronary disease. Intriguingly, the findings of this study indicated that long-term physical exercise did not impart significant effects on adiponectin levels and other adipokines in adipose tissue or plasma among the aforementioned patients. However, a correlation was detected between alterations in circulating adiponectin levels and enhancements in peak VO2.(56)

Outcomes divergent from the previous studies were observed in another research endeavor aiming to investigate the effects of an eight-week aerobic interval exercise regimen on omentin-1, resistin, and adiponectin in elderly men diagnosed with Type II diabetes. The results suggested that the eight-week interval aerobic training resulted in a significant decrease in resistance levels accompanied by a substantial increase in the levels of omentin-1 and adiponectin. Currently, within the context of high-intensity interval aerobic exercises, comparable outcomes have been observed for both short and long-term durations.(57) Additionally, certain studies indicate that physical exercise alone does not significantly alter adiponectin levels, underscoring the need to consider it in conjunction with diet.(3,58)

Within this framework, multiple systematic reviews articulate their findings indicating a positive relationship between physical exercise and adiponectin levels, thereby improving metabolic and cardiovascular health owing to their anti-inflammatory and protective properties.(59) These findings echo those of other systematic reviews with meta-analyses.(60,61) However, another similar study asserts that the relationship between physical exercise and adiponectin may be influenced by other factors, such as diet, hence the combination of both exercise and diet can exert a positive impact on leptin and adiponectin concentrations, which is pertinent for addressing obesity and enhancing metabolic health within this population (DOI: https://doi.org/10.1016/j.advnut.2022.10.001).

Branch 3-Effects

This section primarily identifies the effects of physical exercise on adiponectin levels. Throughout the article, benefits are observed with aerobic physical exercise,[62,63] and metabolic exercise,[64] yet resistance training also presented alterations in adiponectin levels.[20] This emphasizes the significance of physical exercise both at the cardiovascular and muscular levels.

Conversely, physical exercise interventions have been carried out on mice with metabolic syndrome induced by a diet high in fats and sugars. Physical training reversed some adverse effects of the diet, such as improving glucose tolerance and controlling caloric intake. However, no changes were observed in the production of adiponectin (https://doi.org/10.1186/s12986-016-0138-2). Similar studies were performed on diabetic mice in which they found an increase in the expression of AdipoR1 in skeletal muscle and the liver. AdipoR1 could mediate the beneficial effects of adiponectin on glucose and fatty acid metabolism in these tissues.[65,66]

Considering the existent scientific production, there are systematic reviews with meta-analyses that showcase the positive effect of adiponectin levels in relation to physical exercise. However, the duration and intensity of the exercise were factors influencing the results.[60] Regarding intensities, pilates, for instance, is a training method that improves strength, flexibility, balance, and body posture. When combined with celery consumption (a vegetable that can reduce caloric intake and has antioxidant, anti-inflammatory, and diuretic properties), it significantly increases adiponectin levels in women with obesity.[679

There is an expansion in the publication of research manuscripts focused on the adiponectin and physical exercise dyad. To date, up until the year 2022, the topic maintains its relevance, resulting in the United States and Iran emerging as the countries with the most significant scientific output on the subject. Furthermore, the journals offering the most substantial volume of contributions in this field are

"Medicine and Science in Sports and Exercise" and "Plos One", both positioned in the Q1 quartile.

A notable aspect of the analysis is that the majority of nations associated with the citation and academic production regarding adiponectin and physical exercise are located in Europe and North America. However, only three South American countries are represented (Brazil, Mexico, and Colombia). It is noteworthy that the author with the most significant scientific output in this field is of Brazilian nationality, representing 50% of the ten most productive authors.

The implementation of the "tree of science" approach enables the identification of the initial links in the relationships between adiponectin and physical exercise, as well as the optimization of interventions aimed at maximizing protective factors for health and physiological effects in various population groups. These include healthy adults with metabolic, coronary, or cancerous conditions.

Adiponectin levels are mostly modulated by physical exercise, but high-intensity exercise demonstrates greater benefits in terms of training and post-training time. On the other hand, pathologies such as type II diabetes mellitus, inflammation, and obesity show increased adiponectin levels when a physical exercise intervention is introduced. However, the intensity of physical exercise and diet play a crucial role in adiponectin synthesis. There is a need for greater clarity in the association of specific physical exercise methods and types of diet to increase adiponectin levels in humans. Future investigations could corroborate these relationships in patients with cancer or mental illnesses, given the emerging evidence obtained in laboratory rats.

References

1. Deng H, Ai M, Cao Y, Cai L, Guo X, Yang X, *et al*. Potential Protective Function of Adiponectin in Diabetic Retinopathy. Ophthalmol Ther. 2023;12(3):1519-34. DOI: http://dx.doi.org/10.1007/s40123-023-00702-3

2. Tadiotto MC, Corazza PRP, Menezes-Junior FJ de, Moraes-Junior FB de, Tozo TAA, Purim KSM, *et al.* Effects and individual response of continuous and interval training on adiponectin concentration, cardiometabolic risk factors, and physical fitness in overweight adolescents. Eur J Pediatr. 2023;182(6):2881-9. DOI: https://dx.doi.org/10.1007/s00431-023-04974-6

3. Senkus KE, Crowe-White KM, Bolland AC, Locher JL, Ard JD. Changes in adiponectin:leptin ratio among older adults with obesity following a 12-month exercise and diet intervention. Nutr Diabetes. 2022;12(1):30. DOI: http://dx.doi.org/10.1038/s41387-022-00207-1

4. Jiménez-Martínez P, Ramírez-Campillo R, Alix-Fages C, Gene-Morales J, García-Ramos A, Colado JC. Chronic Resistance Training Effects on Serum Adipokines in Type 2 Diabetes Mellitus: A Systematic Review. Healthcare (Basel). 2023;11(4). DOI: http://dx.doi.org/10.3390/healthcare11040594

5. García-Hermoso A, Ramírez-Vélez R, Díez J, González A, Izquierdo M. Exercise training-induced changes in exerkine concentrations may be relevant to the metabolic control of type 2 diabetes mellitus patients: A systematic review and meta-analysis of randomized controlled trials. J Sport Health Sci. 2023;12(2):147-57. DOI: http://dx.doi.org/10.1016/j.jshs.2022.11.003

6. Papagianni G, Panayiotou C, Vardas M, Balaskas N, Antonopoulos C, Tachmatzidis D, *et al.* The anti-inflammatory effects of aerobic exercise training in patients with type 2 diabetes: A systematic review and meta-analysis. Cytokine. 2023;164:156157. DOI: http://dx.doi.org/10.1016/j.cyto.2023.156157

7. Del Rosso S, Baraquet ML, Barale A, Defagó 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. Obes Rev. 2023;24(6):e13564. DOI: http://dx.doi.org/10.1111/obr.13564

8. Botero CM, Milanes CB, Robledo S. 50 years of the Coastal Zone Management Act: The bibliometric influence of the first coastal management law on the world.

Mar Policy. 2023 [access 03/06/2023];150:105548. Available from: https://www.sciencedirect.com/science/article/pii/S0308597X23000751

9. Grisales AM, Robledo S, Zuluaga M. Topic Modeling: Perspectives from a Literature Review. IEEE Access. 2023;11:4066-78. DOI: http://dx.doi.org/10.1109/access.2022.3232939

10. Aria M, Cuccurullo C. bibliometrix: An R-tool for comprehensive science mapping analysis. J Informetr. 2017 [access 03/06/2023];11(4):959-75. Available from: https://www.sciencedirect.com/science/article/pii/S1751157717300500

11. Valencia-Hernandez DS, Robledo S, Pinilla R, Duque-Méndez ND, Olivar-Tost G. SAP Algorithm for Citation Analysis: An improvement to Tree of Science. Ing Inv. 2020 [access 03/06/2023];40(1):459. Available from: https://revistas.unal.edu.co/index.php/ingeinv/article/view/77718

12. Eggers F, Risselada H, Niemand T, Robledo S. Referral campaigns for software startups: The impact of network characteristics on product adoption. J Bus Res [Internet] 2022 [access 03/06/2023];145:309-24. Available from: https://www.sciencedirect.com/science/article/pii/S0148296322002351

13. Aguirre KA, Paredes Cuervo D. Water Safety and Water Governance: A Scientometric Review. Sustain Sci Pract Policy. 2023 [access 03/06/2023];15(9):7164. Available from: https://www.mdpi.com/2071-1050/15/9/7164

14. Nakamura MT, Yudell BE, Loor JJ. Regulation of energy metabolism by long-chain fatty acids. Prog Lipid Res. 2014;53:124-44. DOI: http://dx.doi.org/10.1016/j.plipres.2013.12.001

15. Hosseini M, Bagheri R, Nikkar H, Baker JS, Jaime SJ, Mosayebi Z, *et al*. The effect of interval training on adipokine plasmatic levels in rats with induced myocardial infarction. Arch Physiol Biochem. 2022;128(5):1249-53. DOI: http://dx.doi.org/10.1080/13813455.2020.1764049

16. Mokhtarzade M, Ranjbar R, Majdinasab N, Patel D, Molanouri Shamsi M. Effect of aerobic interval training on serum IL-10, TNFα, and adipokines levels in women

with multiple sclerosis: possible relations with fatigue and quality of life. Endocrine. 2017;57(2):262-71. DOI: http://dx.doi.org/10.1007/s12020-017-1337-y

17. Hejazi K, Wong A. Effects of exercise training on inflammatory and cardiometabolic health markers in overweight and obese adults: a systematic review and meta-analysis of randomized controlled trials. J Sports Med Phys Fitness. 2023;63(2):345-59. DOI: http://dx.doi.org/10.23736/S0022-4707.22.14103-4

18. Lee MK, Kim JY, Kim DI, Kang DW, Park JH, Ahn KY, *et al*. Effect of home-based exercise intervention on fasting insulin and Adipocytokines in colorectal cancer survivors: a randomized controlled trial. Metabolism. 2017;76:23-31. DOI: http://dx.doi.org/10.1016/j.metabol.2017.07.005

19. O'Leary TJ, Walsh NP, Casey A, Izard RM, Tang JCY, Fraser WD, *et al*. Supplementary Energy Increases Bone Formation during Arduous Military Training. Med Sci Sports Exerc. 2021;53(2):394-403. DOI: http://dx.doi.org/10.1249/MSS.0000000000002473

20. Petschnig R, Wagner T, Robubi A, Baron R. Effect of Strength Training on Glycemic Control and Adiponectin in Diabetic Children. Med Sci Sports Exerc. 2020;52(10):2172-8. DOI: http://dx.doi.org/10.1249/MSS.0000000000002356

21. Li XH, Liu LZ, Chen L, Pan QN, Ouyang ZY, Fan DJ, *et al*. Aerobic exercise regulates FGF21 and NLRP3 inflammasome-mediated pyroptosis and inhibits atherosclerosis in mice. PLoS One. 2022;17(8):e0273527. DOI: http://dx.doi.org/10.1371/journal.pone.0273527

22. Huang R, Song C, Li T, Yu C, Yao T, Gao H, *et al*. A cross-sectional comparative study on the effects of body mass index and exercise/sedentary on serum asprosin in male college students. PLoS One. 2022;17(4):e0265645. DOI: http://dx.doi.org/10.1371/journal.pone.0265645

23. Winn NC, Cottam MA, Wasserman DH, Hasty AH. Exercise and Adipose Tissue Immunity: Outrunning Inflammation. Obesity. 2021;29(5):790-801. DOI: http://dx.doi.org/10.1002/oby.23147

24. Ibrahim NE, Januzzi JL Jr, Magaret CA, Gaggin HK, Rhyne RF, Gandhi PU, *et al*. A Clinical and Biomarker Scoring System to Predict the Presence of Obstructive Coronary Artery Disease. J Am Coll Cardiol. 2017;69(9):1147-56. DOI: http://dx.doi.org/10.1016/j.jacc.2016.12.021

25. Olean-Oliveira T, Figueiredo C, de Poli RAB, Lopes VHF, Jiménez-Maldonado A, Lira FS, *et al*. Menstrual cycle impacts adipokine and lipoprotein responses to acute high-intensity intermittent exercise bout. Eur J Appl Physiol. 2022;122(1):103-12. DOI: http://dx.doi.org/10.1007/s00421-021-04819-w

26. Oliveira CLP, Antunes B de MM, Gomes AC, Lira FS, Pimentel GD, Boulé NG, *et al*. Creatine supplementation does not promote additional effects on inflammation and insulin resistance in older adults: A pilot randomized, double-blind, placebo-controlled trial. Clin Nutr ESPEN. 2020;38:94-8. DOI: http://dx.doi.org/10.1016/j.clnesp.2020.05.024

27. Ferreira YAM, Kravchychyn ACP, Vicente S de CF, Campos RM da S, Tock L, Oyama LM, *et al*. An Interdisciplinary Weight Loss Program Improves Body Composition and Metabolic Profile in Adolescents With Obesity: Associations with the Dietary Inflammatory Index. Front Nutr. 2019;6:77. DOI: http://dx.doi.org/10.3389/fnut.2019.00077

28. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetología. 1985;28(7):412-9. DOI: http://dx.doi.org/10.1007/BF00280883

29. Arita Y, Kihara S, Ouchi N, Takahashi M, Maeda K, Miyagawa J, *et al*. Paradoxical decrease of an adipose-specific protein, adiponectin, in obesity. Biochem Biophys Res Commun. 1999;257(1):79-83. DOI: http://dx.doi.org/10.1006/bbrc.1999.0255

30. Hotta K, Funahashi T, Arita Y, Takahashi M, Matsuda M, Okamoto Y, *et al*. Plasma concentrations of a novel, adipose-specific protein, adiponectin, in type 2 diabetic patients. Arterioscler Thromb Vasc Biol. 2000;20(6):1595-9. DOI: http://dx.doi.org/10.1161/01.atv.20.6.1595

31. Hulver MW, Zheng D, Tanner CJ, Houmard JA, Kraus WE, Slentz CA, *et al*. Adiponectin is not altered with exercise training despite enhanced insulin action. Am J Physiol Endocrinol Metab. 2002;283(4):E861-5. DOI: http://dx.doi.org/10.1152/ajpendo.00150.2002

32. Nassis GP, Papantakou K, Skenderi K, Triandafillopoulou M, Kavouras SA, Yannakoulia M, *et al*. Aerobic exercise training improves insulin sensitivity without changes in body weight, body fat, adiponectin, and inflammatory markers in overweight and obese girls. Metabolism. 2005;54(11):1472-9. DOI: http://dx.doi.org/10.1016/j.metabol.2005.05.013

33. Kondo T, Kobayashi I, Murakami M. Effect of exercise on circulating adipokine levels in obese young women. Endocr J. 2006;53(2):189-95. DOI: http://dx.doi.org/10.1507/endocrj.53.189

34. Kriketos AD, Gan SK, Poynten AM, Furler SM, Chisholm DJ, Campbell LV. Exercise increases adiponectin levels and insulin sensitivity in humans. Diabetes Care. 2004;27(2):629-30. DOI: http://dx.doi.org/10.2337/diacare.27.2.629

35. Fatouros IG, Tournis S, Leontsini D, Jamurtas AZ, Sxina M, Thomakos P, et al. Leptin and adiponectin responses in overweight inactive elderly following resistance training and detraining are intensity related. J Clin Endocrinol Metab. 2005;90(11):5970-7. DOI: http://dx.doi.org/10.1210/jc.2005-0261

36. Simpson KA, Singh MAF. Effects of exercise on adiponectin: a systematic review. Obesity. 2008;16(2):241-56. DOI: http://dx.doi.org/10.1038/oby.2007.53

37. Quenan YE, Osorio JH. Relación entre obesidad, adipocitoquinas y osteoatrosis: Una revisión. Univ Salud. 2017 [access 03/06/2023];19(3):410-8. Available from: http://revistas.udenar.edu.co/index.php/usalud/article/view/2779

38. Krause MP, Milne KJ, Hawke TJ. Adiponectin-Consideration for its Role in Skeletal Muscle Health. Int J Mol Sci. 2019;20(7). DOI: http://dx.doi.org/10.3390/ijms20071528

39. Zguira MS, Slimani M, Bragazzi NL, Khrouf M, Chaieb F, Saïag B, et al. Effect of an 8-Week Individualized Training Program on Blood Biomarkers, Adipokines and

Endothelial Function in Obese Young Adolescents with and without Metabolic Syndrome. Int J Environ Res Public Health. 2019;16(5). DOI: http://dx.doi.org/10.3390/ijerph16050751

40. Vints WAJ, Levin O, Fujiyama H, Verbunt J, Masiulis N. Exerkines and long-term synaptic potentiation: Mechanisms of exercise-induced neuroplasticity. Front Neuroendocrinol. 2022;66:100993. DOI: http://dx.doi.org/10.1016/j.yfrne.2022.100993

41. Kon M, Ebi Y, Nakagaki K. Effects of a single bout of high-intensity interval exercise on C1q/TNF-related proteins. Appl Physiol Nutr Metab. 2019;44(1):47-51. DOI: http://dx.doi.org/10.1139/apnm-2018-0355

42. Magherini F, Fiaschi T, Marzocchini R, Mannelli M, Gamberi T, Modesti PA, *et al*. Oxidative stress in exercise training: the involvement of inflammation and peripheral signals. Free Radic Res. 2019;53(11-12):1155-65. DOI: http://dx.doi.org/10.1080/10715762.2019.1697438

43. Costa RR, Buttelli ACK, Vieira AF, Coconcelli L, Magalhães R de L, Delevatti RS, et al. Effect of Strength Training on Lipid and Inflammatory Outcomes: Systematic Review With Meta-Analysis and Meta-Regression. J Phys Act Health. 2019;16(6):477-91. DOI: http://dx.doi.org/10.1123/jpah.2018-0317

44. Luti S, Modesti A, Modesti PA. Inflammation, Peripheral Signals and Redox Homeostasis in Athletes Who Practice Different Sports. Antioxidants (Basel). 2020;9(11). DOI: http://dx.doi.org/10.3390/antiox9111065

45. Gruchowski-Woitowicz FC, Silva CI, Ramalho M. Experimental field test of the influence of generalist stingless bees (Meliponini) on the topology of a bee–flower mutualistic network in the tropics. Ecol Entomol. 2020;45(4):854-66. Available from: https://onlinelibrary.wiley.com/doi/10.1111/een.12862

46. Saeidi A, Haghighi MM, Kolahdouzi S, Daraei A, Abderrahmane AB, Essop MF, *et al*. The effects of physical activity on adipokines in individuals with overweight/obesity across the lifespan: A narrative review. Obes Rev. 2021;22(1):e13090. DOI: http://dx.doi.org/10.1111/obr.13090

47. Ataeinosrat A, Haghighi MM, Abednatanzi H, Soltani M, Ghanbari-Niaki A, Nouri-Habashi A, *et al*. Effects of Three Different Modes of Resistance Training on Appetite Hormones in Males with Obesity. Front Physiol. 2022;13:827335. DOI: http://dx.doi.org/10.3389/fphys.2022.827335

48. Guan Y, Zuo F, Zhao J, Nian X, Shi L, Xu Y, *et al*. Relationships of adiponectin to regional adiposity, insulin sensitivity, serum lipids, and inflammatory markers in sedentary and endurance-trained Japanese young women. Front Endocrinol. 2023;14:1097034. DOI: http://dx.doi.org/10.3389/fendo.2023.1097034

49. Ertekin K, Baştuğ M, Canpolat AG. Effects of Moderate Exercise Training On ApoE and ApoCIII in Metabolic Syndrome. Eur J Ther. 2023 [access 03/06/2023];29(1):65-73. Available from: https://eurjther.com/index.php/home/article/view/184

50. Yang D, Li Y, Fan X, Liang H, Han R. The impact of exercise on serum irisin, osteocalcin, and adiponectin levels and on glycolipid metabolism in patients with type 2 diabetes. Int J Clin Exp Med. 2020 [access 03/06/2023];13:7816-24. Available from: https://e-century.us/files/ijcem/13/10/ijcem0113138.pdf

51. Racil G, Ben Ounis O, Hammouda O, Kallel A, Zouhal H, Chamari K, *et al*. Effects of high vs. moderate exercise intensity during interval training on lipids and adiponectin levels in obese young females. Eur J Appl Physiol. 2013;113(10):2531-40. DOI: http://dx.doi.org/10.1007/s00421-013-2689-5

52. Torabi F, Farahani A, Safakish S, Ramezankhani A, Dehghan F. Evaluation of motor proficiency and adiponectin in adolescent students with attention deficit hyperactivity disorder after high-intensity intermittent training. Psychiatry Res.2018;261:40-4. DOI: http://dx.doi.org/10.1016/j.psychres.2017.12.053

53. Karajibani M, Montazerifar F, Dehghani K, Mogharnasi M, Mousavi Gillani SR, Dashipour A. Effect of aerobic and anaerobic exercises on anthropometric parameters, chemerin and adiponectin levels in non-athletic men. Health Scope. 2018 [access 03/06/2023];7(2). Available from: https://brieflands.com/articles/healthscope-61819.html

54. Jiménez-Maldonado A, Virgen-Ortiz A, Lemus M, Castro-Rodríguez E, Cerna-Cortés J, Muñiz J, et al. Effects of Moderate- and High-Intensity Chronic Exercise on the Adiponectin Levels in Slow-Twitch and Fast-Twitch Muscles in Rats. Medicina. 2019;55(6). DOI: http://dx.doi.org/10.3390/medicina55060291

55. Amani Shalamzari S, Daneshfar A, Hassanzadeh Sablouei M, Fiatarone Singh MA, Kazemi A. The effect of aerobic training on tumor growth, adiponectin, Leptin and ghrelin in mice models of breast cancer. Iran Red Crescent Med J. 2018 [access 03/06/2023];20(2). Available from: https://archive.ircmj.com/article/20/2/ircmj-20-2-13305.pdf

56. Zaidi H, Byrkjeland R, Njerve IU, Åkra S, Solheim S, Arnesen H, et al. Adiponectin in relation to exercise and physical performance in patients with type 2 diabetes and coronary artery disease. Adipocyte.2021;10(1):612-20. DOI: http://dx.doi.org/10.1080/21623945.2021.1996699

57. Kao HH, Hsu HS, Wu TH, Chiang HF, Huang HY, Wang HJ, et al. Effects of a single bout of short-duration high-intensity and long-duration low-intensity exercise on insulin resistance and adiponectin/leptin ratio. Obes Res Clin Pract. 2021;15(1):58-63. DOI: http://dx.doi.org/10.1016/j.orcp.2020.09.007

58. Cipryan L, Dostal T, Plews DJ, Hofmann P, Laursen PB. Adiponectin/leptin ratio increases after a 12-week very low-carbohydrate, high-fat diet, and exercise training in healthy individuals: A non-randomized, parallel design study. Nutr Res. 2021;87:22-30. DOI: http://dx.doi.org/10.1016/j.nutres.2020.12.012

59. Lin H, Hu M, Yan Y, Zhang H. The effect of exercise on adiponectin and leptin levels in overweight or obese subjects: a meta-analysis of randomized controlled trials. Sport Sci Health. 2017;13(2):303-14. DOI: https://doi.org/10.1007/s11332-017-0358-5

60. Yu N, Ruan Y, Gao X, Sun J. Systematic Review and Meta-Analysis of Randomized, Controlled Trials on the Effect of Exercise on Serum Leptin and Adiponectin in Overweight and Obese Individuals. Horm Metab Res. 2017;49(3):164-73. DOI: http://dx.doi.org/10.1055/s-0042-121605

61. Becic T, Studenik C, Hoffmann G. Exercise Increases Adiponectin and Reduces Leptin Levels in Prediabetic and Diabetic Individuals: Systematic Review and Meta-Analysis of Randomized Controlled Trials. Med Sci (Basel). 2018;6(4). DOI: http://dx.doi.org/10.3390/medsci6040097

62. Wang X, You T, Murphy K, Lyles MF, Nicklas BJ. Addition of Exercise Increases Plasma Adiponectin and Release from Adipose Tissue. Med Sci Sports Exerc. 2015;47(11):2450-5. DOI: http://dx.doi.org/10.1249/MSS.0000000000000670

63. Seo DI, So WY, Sung DJ. Changes in insulin resistance and adipokines in obese women following a 12-week programmed of combined exercise training. South African Journal for Research in Sport, Physical Education and Recreation 2016 [access 03/06/2023];38(1):39-147. https://www.ajol.info/index.php/sajrs/article/view/133854

64. Mota GR da, Orsatti FL, Delbin MA, Zanesco A. Resistance exercise improves metabolic parameters and changes adipocyte-derived leptin: a comparison between genders in untrained adults. Motriz: Revista de Educação Física 2016;22:217-22. DOI: https://doi.org/10.1590/S1980-6574201600030014

65. Cho JK, Kim SU, Hong HR, Yoon JH, Kang HS. Exercise Training Improves Whole Body Insulin Resistance via Adiponectin Receptor 1. Int J Sports Med. 2015;36(13):e24-30. DOI: http://dx.doi.org/10.1055/s-0035-1559715

66. Jashni HK, Mohebbi H, Delpasand A, Jahromy HK. Caloric restriction and exercise training, combined, not solely improve total plasma adiponectin and glucose homeostasis in streptozocin-induced diabetic rats. Sport Sci Health. 2015;11(1):81-6. DOI: https://doi.org/10.1007/s11332-014-0212-y

67. Gorji NE, Farzanegi P, Habibian M, Mahdirejei HA, Abadei SFR. Celery as an Effective Supplement for Pilates Exercise in Weight Loss Studies. International Medical Journal 2015 [access 03/06/2023];22(3). Available from: https://openurl.ebsco.com/EPDB%3Agcd%3A14%3A17696798/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A103400502&crl=c&link_origin=none

Conflict of Interests

The authors declare no conflict of interest.

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