Impact of weekly resistance training set volume on adiponectin, TNF-ALFA and leptin levels in obese individuals: a systematic review

Impacto do treinamento semanal de resistência definir o volume nos níveis de adiponectina, TNF-ALFA e leptina em indivíduos obesos: uma revisão sistemática

Impacto del entrenamiento semanal de resistencia en los niveles de adiponectina, TNF-ALFA y leptina en individuos obesos: una revisión sistemática

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ABSTRACT
This literature review study aimed to investigate the impact of different weekly set volumes of resistance training on the levels of adiponectin, TNF-alpha, and leptin, cytokines related to lipoinflammation in obese individuals. The search was carried out in the PubMed and Scielo databases, with a time window of 10 years. The following descriptors were used in the search for articles: (Strength Training OR resistance training OR Strength exercise) AND Leptin AND obesity; (Strength Training OR resistance training OR Strength exercise) AND TNF-alpha AND obesity; (Strength Training OR resistance training OR Strength exercise) AND adiponectin AND obesity. A total of 8 studies were selected and analyzed according to the inclusion criteria. The results revealed that resistance training with higher volumes of weekly sets was more effective in reducing the concentrations of leptin and TNF-α, however, this same pattern did not positively or negatively influence the levels of basal concentrations of adiponectin. Thus, it seems that in obese individuals, greater volumes of weekly sets of resistance training can influence the reduction in the inflammatory environment, mainly reducing TNF-α and Leptin.

Keywords: resistance training, cytokines, inflammation, obesity.

RESUMO
Este estudo de revisão de literatura teve como objetivo investigar o impacto de diferentes volumes semanais de treinamento resistido sobre os níveis de adiponectina, TNF-alfa e leptina, citocinas relacionadas à lipoinflamação em indivíduos obesos. A busca foi realizada nas bases de dados PubMed e Scielo, com janela temporal de 10 anos. Os seguintes descritores foram utilizados na busca dos artigos: (Treinamento de força ou treinamento de resistência ou Exercício de força) e Leptina e obesidade; (treinamento de força ou treinamento de resistência ou exercício de força) e TNF-alfa, e obesidade; (treinamento de força ou treinamento de resistência ou exercício de força) e adiponectina, e obesidade. Um total de 8 estudos foram selecionados e analisados de acordo com os critérios de inclusão. Os resultados revelaram que o treinamento resistido com maiores volumes de séries semanais parece ser mais eficaz na redução das concentrações de leptina e TNF-α, entretanto, esse mesmo padrão não influenciou positiva ou negativamente os níveis das concentrações basais de adiponectina. Ao que parece que em indivíduos obesos, maiores volumes de séries semanais de treinamento resistido podem influenciar a redução do ambiente inflamatório, reduzindo principalmente os níveis basais de TNF-α e a leptina.

Palavras-chave: treinamento resistido, citocinas, inflamação, obesidade.
RESUMEN
Este estudio de revisión bibliográfica tuvo como objetivo investigar el impacto de diferentes volúmenes semanales de entrenamiento de resistencia en los niveles de adiponectina, TNF-alfa y leptina, citocinas relacionadas con la lipoinflamación en individuos obesos. La búsqueda se llevó a cabo en las bases de datos PubMed y Scielo, con una ventana de tiempo de 10 años. Se utilizaron los siguientes descriptores en la búsqueda de artículos: (Entrenamiento de fuerza O entrenamiento de resistencia O ejercicio de fuerza) Y Leptina Y obesidad; (Entrenamiento de fuerza O entrenamiento de resistencia O ejercicio de fuerza) Y TNF-alfa Y obesidad; (Entrenamiento de fuerza O entrenamiento de resistencia O ejercicio de fuerza) Y adiponectina Y obesidad. Se seleccionaron y analizaron un total de 8 estudios de acuerdo con los criterios de inclusión. Los resultados revelaron que el entrenamiento de resistencia con mayores volúmenes de conjuntos semanales fue más efectivo para reducir las concentraciones de leptina y TNF-α, sin embargo, este mismo patrón no influyó positiva o negativamente en los niveles de concentraciones basales de adiponectina. Por lo tanto, parece que en individuos obesos, mayores volúmenes de conjuntos semanales de entrenamiento de resistencia pueden influir en la reducción del ambiente inflamatorio, principalmente reduciendo TNF-α y Leptina.

Palabras clave: entrenamiento de resistencia, citocinas, inflamación, obesidad.

1 INTRODUCTION

Obesity is characterized by excess body fat, caused by a chronic positive energy balance in food (Lamounier and Abrantes, 2013). Nowadays, this body state has become quite common, due to the ease of consumption of foods with high caloric density combined with technological advances that favor the increase in a sedentary lifestyle (Xavier, 2012).

Obesity is defined as having a body mass index (BMI) equal to or greater than 30 kg/m². According to the World Health Organization (WHO), in 2016 more than 1.9 billion adults were overweight, and among them more than 650 million were obese. In Brazil the prevalence of obesity in 2019 was in the order of 20.3% (Vigitel, 2020).

Obesity increases the risk of other metabolic and cardiovascular diseases, such as high blood pressure, type 2 diabetes, and dyslipidemia (Mariath et.al, 2007; Lavie et al, 2009). Luft et al (2013) noted that obese people are six times...
more likely to acquire type 2 diabetes than eutrophic people, a fact that is closely related to the systemic pro-inflammatory environment in the body of obese people, a condition known as lipoinflammation (Villarroya, 2018).

In obese subjects, adipocytes undergo a process of hyperplasia and marked hypertrophy, causing overload in the storage capacity of this tissue, promoting ectopic fat deposits in other tissues, such as skeletal muscle, liver, and visceral adipose tissue (Goossens, 2017). Furthermore, adipose tissue hypertrophy is accompanied by lipid tissue remodeling, closely related to the increased production and secretion of pro-inflammatory modulators, increasing the susceptibility of metabolic alterations in obese individuals (Villarroya, 2018).

Cytokines, when secreted by adipocytes, are called adipokines, among them alpha tumor necrosis factor (TNF-α), leptin, and adiponectin stand out (Izaola, 2015). While leptin and TNF-α present pro-inflammatory characteristics, adiponectin has anti-inflammatory effects, and in obese individuals with chronic lipoinflammation, or chronic low-grade inflammation, production of this adipokine is suppressed (Alaniz et al. 2006). However, exercise and diet seem to positively influence adiponectin levels. The study of Takao (2021), for example, analyzed adiponectin levels in obese people before and after a physical exercise program and dietary guidance. The results showed a mean reduction of 7.5% in body composition and an increase in plasma adiponectin concentrations after the end of the program.

On the other hand, although leptin inhibits lipogenesis and increases lipolysis, high circulating levels of this adipokine contribute to the pro-inflammatory environment in obese individuals (Sanchéz et al., 2011). Physical training seems to be able to reduce the plasma concentration of leptin, as confirmed by the work of Sartorio (2003), who submitted obese subjects to three weeks of combined resistance and aerobic training accompanied by dietary modification. At the end of the program the results demonstrated decreased basal plasma leptin levels. However, the authors noticed a direct relationship between the reduction in adipose mass and the decrease in circulating leptin levels. In
addition, some evidence reveals that physical training can contribute to the reduction in TNF-α levels (Guedes, 2019).

Little is known about the extent to which different weekly volumes of Resistance Training can influence to a greater or lesser extent circulating levels of adipokines in obese individuals, thus leaving important gaps for the ideal prescription of exercises for this population when seeking to reduce the risks associated with the chronic pro-inflammatory environment. The current work aimed to investigate the dose-response relationship of the total weekly set volume of resistance training on circulating basal plasmatic levels of TNF-α, leptin, and adiponectin.

2 METHODOLOGY

The present study is a qualitative bibliographic research with a descriptive character. For this purpose, scientific articles were searched between the years 2012 to 2022, in the PubMed and Scielo electronic databases.

The established inclusion criteria were: a) Randomized controlled studies; b) Studies performed with humans; c) Studies with a training protocol of at least six weeks; d) Studies that evaluate one of the following inflammatory markers: TNFα, Leptin, and Adiponectin.

For the exclusion criteria, the following items were established: a) studies with a literature review; b) case studies; c) studies with diet protocols.

The following descriptors were used in the search for studies: (Strength Training OR resistance training OR Strength exercise) AND Leptin AND obesity; (Strength Training OR resistance training OR Strength exercise) AND TNF-alpha AND obesity; (Strength Training OR resistance training OR Strength exercise) AND adiponectin AND obesity.

Data collection started on March 10, 2022 and continued until May 20, 2022. After the data collection, the studies found were analyzed according to the adopted criteria. The volume of weekly sets was quantified using the number of
exercises multiplied by the number of sets and weekly frequency (Exercises x sets x weekly frequency).

2.1 METHODOLOGICAL QUALITY

The methodological quality of each study was assessed using a modified 11-point scale from the Physical Therapy Evidence Database (PEDro) (Shiwa et al., 2011); the quality of each study was assessed independently by two authors (R.R. and E.N.). As it is not possible to blind participants and researchers in supervised physical exercise interventions, items 5 to 7 of the scale, which are specifically related to blinding, were removed. This approach has been used in previous systematic reviews in the area of RT (Latella et al., 2019; Schoenfeld et al., 2017). After the removal of these items, the maximum score of the modified 'PEDro 8 points' scale was 7, since the first item, referring to the eligibility criteria, is not included in the total score. Qualitative methodology scores were classified in a similar way to previous systematic reviews related to exercises (Latella et al., 2019; Schoenfeld et al., 2017), as follows: 6–7 = 'excellent'; 5 = 'good'; 4 = 'moderate'; and 0–3 = 'bad'.

3 RESULTS

The initial search in the databases identified 401 studies, of which 197 were eliminated after analysis according to the exclusion criteria. Next, the titles and abstracts of 204 articles were analyzed, which led to the removal of 183 studies, leaving 21 studies for full reading and analysis. At this stage, 5 studies were excluded because they were duplicates, 3 because they used aerobic training in conjunction with resistance training, and 5 because they did not describe the training protocol in the methodology, and, thus, only 8 met the defined inclusion criteria (Figure 1).
Studies by Phillips et al, 2012; Tomeleri et al, 2016; Sukala et al, 2012; Ahmad et al, 2021; Al-jiffri and Shehab, 2021; Nikseresht et al, 2014; Ho et al, 2013; Figueroa et al, 2013, met the selection criteria, and the cytokines evaluated before and after a few weeks of resistance training were leptin, TNF-α and Adiponectin (Table 1).

Table 1: Selected studies and their respective sample, interventions, VWS, cytokines evaluated and results sample, interventions, VWS, cytokines evaluated and results.

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>SAMPLE</th>
<th>INTERVECTION</th>
<th>VWS</th>
<th>CYTOKINES</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philips et al, 2012</td>
<td>Postmenopausal women (n-23) between 60 and 70</td>
<td>12 weeks of intervention, 3 weekly sessions, 3 sets per exercise, 10 exercises per session.</td>
<td>90</td>
<td>Leptin, TNF-α and Adiponectin.</td>
<td>TNF-α and leptin were significantly reduced. Adiponectin levels did not change.</td>
</tr>
<tr>
<td></td>
<td>years old and BMI between 30-40 kg.m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomeleri et al, 2016</td>
<td>Women (n-35); average age ≥60 years, body fat percentage ≥32</td>
<td>8 weeks of intervention, 3 sessions per week, 3 sets per exercise, 8 exercises per session.</td>
<td>72</td>
<td>TNF-α</td>
<td>Significant reduction in TNF-α.</td>
</tr>
<tr>
<td>Sakala et al, 2012</td>
<td>Women (n-18) with type II diabetes, mean age 49.3 ± 5.3</td>
<td>16 weeks of intervention, 3 sessions per week, 2</td>
<td>48-72</td>
<td>Adiponectin</td>
<td>No significant changes in adiponectin.</td>
</tr>
<tr>
<td>Study</td>
<td>Group Details</td>
<td>Intervention Details</td>
<td>PEDro Score</td>
<td>Outcome</td>
<td>Result</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------------</td>
<td>-------------</td>
<td>---------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Ahmad et al, 2021</td>
<td>Men and women (n=225), average of 34.2± 8.9 years, BMI between 30 and 40</td>
<td>8 weeks of intervention, 3 sessions per week, 3 sets per exercise and 10 exercises per session.</td>
<td>90</td>
<td>Leptin and Adiponectin</td>
<td>Leptin significantly reduced in adiponectin significantly increased.</td>
</tr>
<tr>
<td>Al-jiffri e Shehab, 2021</td>
<td>Men and women (n -60) Average of 43.64 + 3.97 years and BMI: 34.19 + 3.41 kg/m²</td>
<td>24 weeks of intervention, 3 sessions per week, 3 sets per exercise and 8 exercises per week.</td>
<td>72</td>
<td>TNF- α</td>
<td>No significant change in TNF- α</td>
</tr>
<tr>
<td>Nikseresht et al, 2014</td>
<td>Obese men (n-34), between 34 and 46 years old.</td>
<td>12-week intervention, 3 sessions per week, 3 sets per exercise and 12 exercises per week.</td>
<td>108</td>
<td>TNF- α</td>
<td>Significant reduction in TNF-α levels</td>
</tr>
</tbody>
</table>

Legenda: VWS: volume of weekly sets; BMI: body mass index; n: number of subjects in the sample
Source: Authors.

The PEDro scale scores for the studies in this review ranged from 4 to 6 (mean=4.75±0.8) (Table 2); 2 received a total score of 6, 2 a total score of 5, and 4 a total score of 4. These results indicate that the evidence used in this review was generated in studies with a methodological quality from “moderate” to “excellent”.

<table>
<thead>
<tr>
<th>years, BMI: 43.8 ±9.5 kg/m².</th>
<th>to 3 sets per exercise and 8 exercises per session.</th>
<th>8 weeks of intervention, 3 sessions per week, 3 sets per exercise and 10 exercises per session.</th>
<th>90</th>
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Table 2: Assessment of the methodological quality of the randomized clinical trials according to the Physiotherapy Evidence Database scale (PEDro).

<table>
<thead>
<tr>
<th>Articles</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillips et al., 2012</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>6/7</td>
</tr>
<tr>
<td>Tomeleri et al., 2016</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>6/7</td>
</tr>
<tr>
<td>Sakala et al., 2012</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>4/7</td>
</tr>
<tr>
<td>Ahmad et al., 2021</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>4/7</td>
</tr>
<tr>
<td>Al-jiffri and Shehab, 2021</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>5/7</td>
</tr>
<tr>
<td>Nikseresht et al., 2014</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>4/7</td>
</tr>
<tr>
<td>Ho et al., 2013</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>4/7</td>
</tr>
<tr>
<td>Figueroa et al., 2013</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>5/7</td>
</tr>
</tbody>
</table>

PEDro scale items: 1= Eligibility criteria have been specified. 2= Subjects were randomly assigned to groups. 3= The allocation of subjects was secret. 4= Initially, the groups were similar with respect to the most important prognostic indicators. 8= Measurements of at least one key outcome were obtained in more than 85% of the subjects initially assigned to the groups. 9= All subjects from whom outcome measurements were presented received the treatment or control condition as allocated or, when this was not the case, data analysis was performed for at least one of the key outcomes by “intent to treat” 10= Results of intergroup statistical comparisons were described for at least one key outcome. 11= The study has both precision measures and variability measures for at least one key outcome.

Source: Authors.

Circulating Leptin levels were analyzed in 3 studies, with 289 adults. The participants included postmenopausal women (Phillips et al, 2012; Figueroa et al, 2013) and middle-aged women and men (Ahmad et al, 2021). In these studies, strength training ranged from 8 to 12 weeks, with a frequency of 3 times a week. All exercises were performed in three sets, and the number of exercises varied from 4 (Figueroa et al, 2013) to 10 exercises per session (Phillips et al, 2012; Ahmad et al, 2021).

Circulating leptin levels significantly reduced in the resistance training group in the studies by Phillips et al (2012), from 40±5 to 33±5 ng.ml., and in the study by Ahmad et al (2021), from 28.6 ±7.1 to 14.4 ±5.6, both studies used 90 weekly sets in their experimental protocols. On the other hand, Figueroa et al (2013) included around 36 weekly sets and the results showed an increase in
leptin concentration after 12 weeks of strength training, from 43.6 ± 5.2 to 46.2 ± 6.6 ng.ml (table 2).

<table>
<thead>
<tr>
<th>STUDY</th>
<th>WEEKLY VOLUME</th>
<th>ALTERATION IN CYTOKINE</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillips et al, 2012</td>
<td>90 sets</td>
<td>-17.5%</td>
<td>(p&lt;0.05)</td>
</tr>
<tr>
<td>Ahmad et al, 2021</td>
<td>90 sets</td>
<td>-50.3%</td>
<td>(p≤0.05)</td>
</tr>
<tr>
<td>Figueroa et al, 2013</td>
<td>36 sets</td>
<td>-</td>
<td>(p=0.58)</td>
</tr>
</tbody>
</table>

*p≤ 0.05= significant. P>0.05= not significant.
Source: Authors.

Circulating levels of TNF-α were analyzed in 5 studies, with 216 adults, including postmenopausal women (Phillips et al, 2012), older women (Tomeleri et al, 2016) and middle-aged men and women (Al-Jiffri and Shehab 2021; Nikseresht et al, 2014; HO et al, 2013). The strength training protocol was 8 weeks in the study by Tomeleri et al. (2016), 12 weeks in the studies by Phillips et al. (2012), Nikseresht et al., (2014), and Ho et al. (2013), and 24 weeks in the study by Al-jiffri and Shehab (2021), all with a frequency of 3 times a week, except for one study that subsequently increased the frequency to 5 times a week (HO et al, 2013). The exercises were performed in 3 sets, ranging among 8 exercises (Tomeleri et al, 2016; Al-Jiffri and Shehab, 2021), 10 exercises (Phillips et al, 2012), and 12 exercises (Nikseresht et al, 2014). In another study, three times a week the experimental group trained at the gym using 4 sets of 5 exercises and twice a week the group trained at home using 3 sets of 5 exercises (Ho et al, 2013).

In the five studies that evaluated TNF-α, four reported a significant reduction after strength training. The study by Phillips et al (2012) included 90 weekly sets and among the studies these results showed the highest levels of reduction, around 29%. On the other hand, Nikseresht et al (2014) included the highest volumes of weekly sets but obtained a reduction in TNF-α of approximately 11%. Ho et al (2013) also included an exercise protocol with a high
weekly volume of sets, 105 sets, and observed a large reduction in TNF-α levels, on average 26.9%, in the group that performed strength training.

The studies by Al-Jiffri and Shehab (2021) and Tomeleri et al (2016) used the lowest weekly series volumes among the five studies that evaluated TNF-α, 72 sets. Despite this, the authors reported contrasting results; while the first did not show a significant reduction in TNF-α levels, around 2.17%, Tomeleri et al (2016) reported a significant reduction of around 24.4%, ranging from 4.2±2.5 to 3.1±1.5 pg.ml (Table 3).

<table>
<thead>
<tr>
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</tr>
<tr>
<td>Tomeleri et al, 2016</td>
<td>72 sets</td>
<td>-24.4%</td>
<td>(p&lt;0.01)</td>
</tr>
<tr>
<td>Nikseresht et al, 2014</td>
<td>108 sets</td>
<td>-11%</td>
<td>(p≤0.05)</td>
</tr>
<tr>
<td>Ho et al, 2013</td>
<td>105 sets</td>
<td>-26.9%</td>
<td>(p=0.01)</td>
</tr>
<tr>
<td>Al-jiffri and Shehab, 2021</td>
<td>72 sets</td>
<td>-</td>
<td>(p&gt;0.05)</td>
</tr>
</tbody>
</table>

*p≤ 0.05= significant. P>0.05= not significant.
Source: Authors.

Circulating levels of adiponectin were analyzed in 4 studies, with 307 adults, including postmenopausal women (Phillips et al, 2012; FIGUEROA et al, 2013), middle-aged women and men (Ahmad et al, 2021), and obese women with type II diabetes (Sukala et al, 2012). The strength training protocols ranged among 8 weeks (Ahmad et al, 2021), 12 weeks (Phillips et al, 2012; Figueroa et al, 2013), and 16 weeks (Sukala et al, 2012). One study performed 2 to 3 sets (Sukala et al, 2012) and the others performed 3 sets of work for each exercise, which ranged from 4 exercises per session (Figueroa et al, 2013), 8 exercises per session (Sukala et al., 2012), and 10 exercises per session (Phillips et al, 2012; Ahmad et al, 2021). All studies included a weekly frequency of 3 times a week.

The study by Ahmad et al (2021) used the highest weekly volume of sets, 90 sets, and resulted in an increase in adiponectin levels, from 6.57±1.5 to
10.33±1.7, an increase of approximately 57%. However, Phillips et al (2012) used the same volume and did not observe changes in adiponectin concentration. Sukala et al (2012), included between 48 and 72 weekly sets and Figueroa et al (2013) used only 36 sets, and neither author reported significant changes in adiponectin levels, with a tendency to decrease of approximately 11.7% in the work of Figueroa et al (2013).

<table>
<thead>
<tr>
<th>STUDY</th>
<th>WEEKLY VOLUME</th>
<th>ALTERATION IN CYTOKINE</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmad et al, 2021</td>
<td>90 sets</td>
<td>+57%</td>
<td>(p≤0.05)</td>
</tr>
<tr>
<td>Phillips et al, 2012</td>
<td>90 sets</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sukala et al, 2012</td>
<td>48 to 72 sets</td>
<td>-</td>
<td>(p=0.96)</td>
</tr>
<tr>
<td>Figueroa et al, 2013</td>
<td>36 sets</td>
<td>-</td>
<td>(p=0.11)</td>
</tr>
</tbody>
</table>

p≤ 0.05= significant. P>0.05= not significant.
Source: Authors.

4 DISCUSSION

The results of the current study showed that alterations in cytokine concentrations may be related to the weekly set volume (WSV). For TNF-α and leptin, the results indicate that a higher WSV can promote greater reductions in the basal levels of these cytokines, when compared with low volumes. However, for adiponectin the data are still inconclusive, only one study with high WSV showed an increase (Ahmad et al, 2021). In general, the results indicate that between 72 and 108 weekly sets of resistance training exercises can positively impact the reduction in the systemic pro-inflammatory environment in obese individuals.

Among the studies that investigated TNF-α, three reported a reduction above 25% (Phillips et al, 2012; Tomeleri et al, 2016; Ho et al, 2013), and all used a weekly volume greater than 72 sets. In the study by Phillips et al (2012), a volume of 90 weekly sets led to a reduction in TNF-α in postmenopausal women. These results are in line with the findings of Flynn et al (2003) who observed that trained individuals present lower concentrations of this adipokine, in addition to
presenting a lower expression of TLR4 (Toll-like receptor 4), which is a receptor related to the recognition of pathogens. Low concentrations of this receptor enable lower pro-inflammatory responses when the body is exposed to inflammatory agents.

In the study by Tomeleri et al (2016), a weekly volume of 72 sets was used in postmenopausal women and the reduction of TNF-α was accompanied by loss of body fat. However, fat loss should not be associated only with the volume of training, since in the study by Philips et al (2012) a larger volume of training was used and this reduction did not occur. It should also be considered that weight reduction can influence the decrease in TNF-α concentration, since the amount of body fat is inversely proportional to the expression of this cytokine (Ouchi et al, 2012).

Another difference in the results that may have influenced the fat loss values obtained refers to the work of Tomeleri et al (2016) and Al-Jiffri and Shehab (2021), since both used the same 72 weekly sets, but while the first reported a decrease in body fat and circulating TNF-α levels, in the second the results did not show loss of body fat in the subjects or reductions in TNF-α levels, even after 24 weeks of resistance training (2021).

Weekly volumes greater than 100 weekly sets also led to reductions in TNF-α. In the study by Ho et al (2013) that included 105 weekly sets, an average reduction of 26.9% was observed in the experimental group of resistance training, while in the study by Nikseresht et al (2014) an average reduction of 11% was obtained for the resistance training group that trained with a total volume of 108 sets.

Leptin levels were positively correlated with higher weekly resistance training volumes. The studies by Phillips et al (2012) and Ahmad et al (2021) used 90 weekly sets and the authors reported reductions of 29% and 50.3% in leptin concentrations, respectively. These results are in agreement with those of Klinkova et al (2006) who also revealed significant results in leptin levels after using high WSV.
On the other hand, the study by Figueroa et al (2013), which included a WSV of 36 sets, and that of Ryan et al (2000), which used only 53 weekly sets, did not demonstrate a reduction in leptin levels in the training groups. Larger volumes are more effective in also reducing abdominal circumference, which is related to a decrease in leptin (Nunes et al, 2016; Dâmaso et al, 2021; Huxley et al, 2010). These results generally indicate that higher doses of resistance training seem to be more conducive to the reduction in pro-inflammatory adipokines, contributing to modify the status of the inflammatory environment in obese individuals.

Analysis of the results related to adiponectin demonstrated that weekly volume doses between 72 and 36 sets do not seem to have any influence on the levels of this anti-inflammatory adipokine. With a dosage of 90 weekly sets, the results were conflicting, because while the study by Phillips et al (2012) which included 90 WSV and 12 weeks of training was not able to change the concentrations of this adipokine, Ahmad et al (2021) used the same 90 weekly sets in 8 weeks and obtained an average increase of 57% in adiponectin concentrations in the experimental group after the training. Furthermore, in a previous study Ahmadizad et al (2007) used an even greater WSV, of 132 weekly sets, and yet at the end of the training no alterations were observed in the concentrations of adiponectin, which demonstrates that there may be a WSV zone that guarantees better results.

In summary, these results may indicate that there is an ideal WSV cut-off point to induce improvements in the concentrations of these adipokines. Although the majority of the results indicated that a high WSV is important to induce beneficial alterations in the basal levels of these cytokines, very high volumes may have a negative impact on these processes.

5 CONCLUSION

The current study investigated the impact of weekly set volume on inflammatory cytokines in obese individuals, with the aim of clarifying whether
there is a dose response for this effect. Although there are still many gaps in the literature about the effects of resistance training on the basal levels of adipokines in obese conditions, the results of this review point to the fact that a larger WSV seems to be more effective to reduce circulating levels of TNF-α and leptin, while, for adiponectin, data are still conflicting. In summary, the findings indicate that weekly volumes of resistance training of between 72 and 108 sets can positively impact the systemic inflammatory environment in obese individuals.
REFERENCES


Guedes JM, Pieri BLS, Luciano TF, Marques SO, Guglielmo LGA, Souza CT. Exercícios físicos de resistência, hipertrofia e força muscular reduzem igualmente adiposidade, inflamação e resistência à insulina em camundongos obesos por dieta hiperlipídica. einstein (São Paulo). 2019;18:eAO4784.
Ho SS, Dhaliwal SS, Hills AP, Pal S. Effects of chronic exercise training on inflammatory markers in Australian overweight and obese individuals in a randomized controlled trial. Inflammation.


Pi-Sunyer FX. The obesity epidemic: pathophysiology and consequences of obesity. Obes Res. 2002 Dec;10 Suppl 2:97S-104S.


