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SUMARIO ● SUMMARY ● RESUMO

Footprint Analysis in Children Aged 5 to 11 Years: A Study in the City of Quito

Editorial

In this first issue of the fifth volume of MLS Health & Nutrition Research, we present an issue that once again reflects the breadth and depth of current research in health, nutrition, and related fields. The studies included address issues that are very common in professional practice and everyday life: managing excess weight, dietary quality among adolescents and athletes, the role of nutritional supplementation, virtual health interventions, and the importance of early assessment of conditions that may affect future well-being.

We open this issue with an article on the effect of intermittent fasting on weight and body composition in men and women who are overweight, obese, or have early-stage metabolic syndrome. The review examines different forms of intermittent fasting and their potential impact on weight, body composition, and certain metabolic parameters. The results suggest that this may be a useful and well-tolerated strategy in certain contexts, although they also highlight the need for further research into its adherence, safety, and long-term efficacy, especially when it is considered as a nutritional intervention tool for populations at metabolic risk.

The second study, titled "Description of Risky Eating Habits and Behaviors Among Adolescents at a University in Guanajuato," focuses on a particularly sensitive stage for the establishment of eating patterns. By assessing consumption habits and risky behaviors, the study highlights the need to strengthen educational and preventive measures in academic settings. Beyond the data, the article invites readers to reflect on the role of educational institutions in promoting a healthier relationship with food from an early age.

From the field of sports nutrition, the article "Nutritional Supplementation for Recovery from Exercise-Induced Muscle Damage: Omega-3 Fatty Acids, Curcumin, and Collagen" reviews the available evidence on three supplements commonly used in the context of physical exercise. The results paint a picture that remains mixed, showing potential benefits under certain conditions, but also significant methodological limitations. This study is particularly important because it helps place supplementation within a prudent, evidence-based framework, rather than relying on generalized recommendations that lack sufficient scientific support.

The fourth article, "Impacts of a Holistic Virtual Program on Nutritional Status, Eating Habits, Physical Activity Levels, and Health in Overweight or Obese Adults," provides a current perspective on digital health interventions. The study evaluates an online program designed to improve eating habits, physical activity, and overall well-being in overweight individuals. Their results show positive changes in various indicators and highlight the potential of digital tools when combined with guidance, nutrition education, and behavioral support strategies.

The relationship between diet, body composition, and sports participation is also addressed in the study "Body Composition and Dietary Intake in Male Amateur Rugby

Players in the U15 and U16 Youth Divisions of Tigres Rugby Club, San Lorenzo." This research allows us to gain insight into a population of young athletes in which performance, growth, and dietary quality must be analyzed together. Although no statistically significant associations were observed between body composition and dietary intake, the results indicate room for improvement in macronutrient distribution and diet quality, particularly due to the high consumption of ultra-processed foods and the low intake of fruits and vegetables.

This issue concludes with the article "Analysis of Footprints in Children Aged 5 to 11: "Study in the City of Quito," which broadens the journal's scope to include pediatric podiatric and biomechanical assessment. The study describes the presence of various gait abnormalities in school-aged children and emphasizes the importance of early assessments to detect potential problems in motor development and future quality of life. Their contribution is particularly valuable because it generates local evidence in an area that remains largely unexplored in the context under study.

Overall, this issue brings together a variety of research studies that are united by a common idea: health and nutrition must be approached from a comprehensive, context-specific perspective that is closely aligned with the actual needs of the population. Scientific research cannot be limited to merely describing problems; it must also help us better understand them, guide decision-making, and open up new possibilities for intervention.

In an age when information circulates rapidly but not always with the necessary rigor, MLS Health & Nutrition Research aims to remain a space where evidence leads to dialogue, knowledge informs professional judgment, and research creates opportunities to improve people's health.

Each issue of the journal is also an invitation to look beyond the specific results of each study: to ask ourselves how they can be applied, who they can benefit, and what new questions they raise for the scientific community. That is probably one of the greatest values of research: not closing off paths, but opening them up.

We sincerely thank the authors, reviewers, and readers who are part of this publishing project. Their commitment allows the magazine to continue growing as a hub for a more critical, more humane approach to nutrition—one that is more closely connected to the real challenges facing our society.

Dr. Iñaki Elío Pascual
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EFFECT OF INTERMITTENT FASTING ON WEIGHT AND BODY COMPOSITION IN MEN AND WOMEN WITH OVERWEIGHT, OBESITY, AND EARLY METABOLIC SYNDROME

Efecto del ayuno intermitente en el peso y la composición corporal en hombres y mujeres con sobrepeso, obesidad y síndrome metabólico incipiente

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ABSTRACT

This study aimed to evaluate the effect of intermittent fasting on body weight and composition in men and women with overweight, obesity, and early-stage metabolic syndrome. Additionally, it sought to assess its impact on key metabolic parameters, compare its effectiveness to classical caloric restriction, and examine adherence and potential adverse events.
A narrative review of recent scientific literature was conducted, focusing on studies published between 2020 and 2025 in English. Sources included PubMed and Google Scholar. Inclusion criteria comprised original research in human participants over 19 years of age. Meta-analyses and review articles were excluded.
The reviewed studies suggest that intermittent fasting, whether through time-restricted eating (TRE), alternate-day fasting (ADF), modified alternate-day fasting (MADF), or prolonged fasting (PF), is an effective and generally well-tolerated strategy for weight loss. Some protocols also demonstrated additional benefits on glycemic and lipid profiles. However, evidence regarding long-term adherence and adverse effects remains scarce. Despite some limitations in the current body of evidence, findings support the potential of intermittent fasting as a viable nutritional intervention. Further high-quality research with longer follow-up periods and diverse populations is warranted to better determine its long-term efficacy, safety, and sustainability. Intermittent fasting could be considered a complementary tool in nutritional therapy, either as a stand-alone approach or in combination with conventional dietary strategies, provided it is implemented under appropriate professional guidance.

Palabras clave:

RESUMEN

El objetivo de esta investigación fue evaluar el efecto del ayuno intermitente sobre el peso y la composición corporal en hombres y mujeres con sobrepeso, obesidad y síndrome metabólico incipiente.

Ayuno intermitente, Pérdida de peso, Sobrepeso, Síndrome metabólico, Efectos adversos	Además, se analizó su impacto sobre parámetros metabólicos clave, su eficacia comparada con la restricción calórica clásica, la adherencia y la aparición de eventos adversos. Se realizó una revisión narrativa de la literatura científica publicada entre 2020 y 2025, en idioma inglés, a través de bases de datos como PubMed y Google Académico. Se aplicaron filtros que incluyeron estudios en humanos mayores de 19 años, excluyendo revisiones y metaanálisis, y limitando la búsqueda a los últimos cinco años. Los estudios incluidos indican que el ayuno intermitente, en sus distintas modalidades; alimentación con restricción de tiempo (RET), ayuno en días alternos (ADF), ayuno modificado en días alternos (MADF) y ayuno prolongado (AF), resulta una estrategia eficaz y bien tolerada para la reducción de peso. En algunos casos, se observaron mejoras adicionales en parámetros glucémicos y lipídicos. No obstante, la evidencia relacionada con la adherencia a largo plazo y los posibles efectos adversos aún es escasa. A pesar de las limitaciones encontradas, los resultados respaldan el potencial del ayuno intermitente como herramienta de intervención nutricional. Se sugiere profundizar en estudios de mayor duración y con poblaciones diversas, para validar su eficacia y seguridad a largo plazo bajo supervisión profesional.

Introduction

It is projected that by 2035, more than 4 billion people worldwide will be overweight or obese, an increase from the 2.6 billion recorded in 2020. This increase represents a rise from 38% to 50% of the world's population during that period. As for obesity, it is projected to rise from 14% to 24% of the population, affecting nearly 2 billion adults, children, and adolescents (1).

Obesity is a chronic, multifactorial disease characterized by excess body fat, which has negative health implications. This condition significantly increases the risk of developing other diseases, such as type 2 diabetes and cardiovascular problems, and also negatively impacts bone and reproductive health, potentially leading to the onset of metabolic syndrome. It is also associated with an increased risk of certain types of cancer and affects quality of life in key areas such as sleep and physical mobility. (1, 2, 4 – 6).

Over the past decade, the focus on nutrition has shifted from the Mediterranean diet toward trends such as the ketogenic diet, low-carb diets, and extended fasting. Fasting, defined as abstaining from food and caloric beverages—whether for therapeutic, spiritual, religious, or even fashion-related reasons—has been shown to have various physiological benefits. (3)

Although improvements in weight and body fat reduction have been observed, it is essential to establish clear guidelines for fasting and non-fasting days in order to optimize adherence and maximize the benefits in terms of body composition. Despite the available evidence on fasting and calorie restriction, there is still no safe, standardized protocol to guide nutritionists and health professionals. Therefore, it is crucial to explore this topic in greater depth in order to maximize its benefits in clinical practice. Fasting is part of daily life for the entire population; it is an inevitable physiological process, as it occurs naturally during periods when no food is consumed. Therefore, understanding and learning more about it is crucial for managing it properly (4–10).

Given the above, the objective of this study was to evaluate the effect of intermittent fasting on weight and body composition in men and women who are overweight, obese, or have early-stage metabolic syndrome. In addition, the study analyzed its impact on key metabolic parameters, its efficacy compared to traditional calorie restriction, adherence, and the occurrence of adverse events.

Method

A narrative review of the scientific literature was conducted. To ensure the relevance and timeliness of the articles analyzed, a structured search strategy was used to analyze recent evidence on the effects of intermittent fasting (IF) on body composition and metabolic parameters in overweight or obese individuals.

The search for articles was conducted between February and March 2025. The primary database used was PubMed. In addition, Google Scholar was used as a supplementary source to identify relevant studies that might not have been indexed in the main search.

The keywords used, in various Boolean combinations (AND/OR), included: "intermittent fasting," "fasting," "weight loss," "metabolic syndrome," and "calorie restriction."

The following inclusion criteria were established: clinical trials in humans; study population aged 19 years or older, who were overweight, obese, or had early-stage

metabolic syndrome; articles published in the last 5 years (January 2020–March 2025); and articles in English.

The following exclusion criteria were applied: literature reviews, systematic reviews, and meta-analyses; studies in animal models; and study protocols, editorials, or letters to the editor. The initial search using those keywords yielded a large number of results. To manage the selection process, a two-phase screening process was implemented:

Phase 1: The titles and abstracts of all identified articles were reviewed to exclude duplicates and those that clearly did not meet the inclusion criteria (e.g., reviews, animal studies).

Phase 2: A full-text review of the shortlisted articles was conducted.

Since the objective was to conduct a narrative review, the final selection was not intended to be exhaustive (as in a systematic review), but rather representative. Priority was given to clinical trials that provided relevant data on the various types of AI (RET, ADF/MADF, etc.), their effect on body composition, and adherence. Through this qualitative selection process, a final set of 14 articles was identified that were considered the most relevant and methodologically sound for the analysis and discussion in this study.

Discussion and Conclusions

The implementation of intermittent fasting through a restricted eating window (RET), particularly using the 16:8 protocol (which involves fasting for 16 hours and limiting food intake to an 8-hour window), has been evaluated in various clinical trials as a strategy to improve body composition, glycemic control, and metabolic parameters in people who are overweight, obese, or at risk of developing metabolic diseases. Most of the selected studies agree that there are positive short- and medium-term effects (6, 7, 9–11), although there are nuances depending on the study population and the intervention design, as shown in Table 1.

Several controlled trials have demonstrated the effectiveness of the 16:8 intermittent fasting regimen in overweight or obese adults. For example, the study by Schroder et al. (6) In middle-aged women, it resulted in significant reductions in body weight, total body fat, and waist circumference. Furthermore, that study observed a decrease in BMI without significant changes in metabolic markers, leading the authors to conclude that RET is an effective strategy for weight loss and reducing cardiovascular risk (6), suggesting that the benefits may be primarily mediated by fat loss. This anthropometric improvement could have a positive impact on adherence.

Similarly, Kotarsky et al. (10) found that RET 16:8, compared with a normal diet, resulted in greater weight loss (-3.3%) and body fat loss (-9.0%). This finding allowed them to propose RET as an effective short-term strategy for reducing body fat and increasing lean body mass in overweight and obese adults (10).

Along the same lines, Sukkriang et al. (7) and Teong et al. (11), using larger sample sizes and comparisons with other groups, also demonstrated significant improvements in fasting glucose, HbA1c, and lipid profile. In fact, Sukkriang et al. (7) concluded that both the 16:8 and 14:10 diets showed clear benefits in terms of weight loss, improved glycemic control, and lipid profile. For its part, the study by Teong et al. (11), which included a longer follow-up period, highlighted a greater improvement in glucose tolerance compared with conventional calorie restriction, validating RET as a superior alternative

for this parameter (11). However, it is important to note that this latest study also reported mild side effects (fatigue, headache, constipation), which underscores the importance of adapting the protocol.

Finally, Domaszewski et al. (9) provided relevant evidence regarding older adults, an underrepresented population. Although weight loss was observed across the board, the reduction in visceral fat and waist circumference was significant only in men. As the authors point out, this intervention was effective in reducing weight in both sexes, but the difference in visceral fat suggests an interaction between biological sex and the physiological response to RET (9). The high adherence rate (>98%) suggests that this strategy may also be feasible in the context of healthy aging.

Overall, the studies reviewed suggest that the 16:8 intermittent fasting regimen is an effective and generally well-tolerated intervention for improving body weight, with potential additional metabolic benefits. However, this conclusion should be viewed with caution due to persistent methodological limitations in this set of studies. The short duration of the interventions (typically 6–12 weeks) is a critical factor; for example, the high adherence (>98%) reported by Domaszewski et al. (9) In older adults, this is a promising finding, but it is unclear whether this sustainability could be maintained at a 6- or 12-month follow-up. In addition, the lack of robust control groups in some study designs makes it difficult to isolate the effect of the time-of-day pattern. Non-randomized studies, such as the one by Schroder et al. (6) do not rule out the possibility that the observed benefits stem from spontaneous calorie restriction rather than from fasting itself. Finally, there is considerable heterogeneity in the metabolic results: while Teong et al. (11) reported clear improvements in glucose tolerance, Schroder et al. (6) They found no significant changes in biomarkers. This discrepancy underscores that the physiological mechanisms have not yet been fully elucidated, and the adverse effects—although mild (11)—must be taken into account during clinical follow-up.

Table 1 Studies on RET fasting and a control group in people who are overweight, obese, and/or have early-stage metabolic syndrome.

Author, year	Study Design	Population	N (Sample)	Duration	Speech	Key Findings
Schroder et al. 2021. (6)	Non-randomized controlled clinical trial	Middle-aged obese women.	32 (RET = 20, Control 12)	3 months	RET (16:8) vs. Control	Weight loss (-4 kg; $p < 0.05$), decrease in BMI ($p < 0.05$), % Body Fat, and Circ. Waist circumference ($p < 0.05$). (No changes in biomarkers; $p > 0.05$).
Sukkriang, et al. 2024. (7)	Randomized Controlled Clinical Trial	Adults with obesity	99 (in 3 groups)	3 months	RET (16:8) vs. RET (2:10 PM) vs. Control	Significant weight loss in RET groups (vs. Control; $p < 0.001$). Greater weight loss with the 16:8 diet than with the 14:10 diet ($p < 0.001$). Significant improvements in glucose and lipid profile (vs. Control).
Domaszewski et al. 2023. (9)	Randomized clinical trial	Overweight older adults (ages 65–74)	166	6 weeks	RET (16:8) vs. Control	Weight Loss (Men: -1.8 kg; Women: -1.3 kg; $p = 0.03$). Men: Reduction in visceral fat ($p <= 0.001$) and Circ. Waist circumference ($p <= 0.015$). (Women with no significant changes in body fat or waist circumference; $p > 0.05$).
Kotarsky et al. 2021. (10)	Randomized Controlled Clinical Trial	Adults who are overweight or obese	21	8 weeks	RET (16:8) vs. Control	Weight loss (-3.3%; $p < 0.05$ vs. control) and body fat reduction (-9.0%; $p < 0.05$ vs. control) in the RET group.
Teong, et al. 2023. (11)	Randomized, controlled clinical trial	Adults at Risk for Type 2 Diabetes	209	6 months (12-week follow-up)	RET + Calorie Restriction vs. Classic Calorie Restriction vs. Control	Greater improvement in glucose tolerance in the RET group (vs. RCC; $p = 0.03$ at 6 months). (Mild and transient adverse effects reported: fatigue, headache, constipation).

In addition to the 16:8 protocol, other forms of intermittent fasting have been studied, such as alternate-day fasting (ADF) and its modified version (MADF), which have shown positive effects on body composition and metabolic variables in overweight or obese individuals (4,8,12,13–15). Although the mechanisms of action differ, studies consistently show clinically relevant benefits, with some variations depending on the protocol, as summarized in Table 2.

As for the ADF, the studies by Chair et al. (4) and Ekberg et al. (15) compared this protocol with other approaches. Chair et al. (4) highlighted greater weight loss and BMI reduction in the ADF group compared with RET, concluding that, although both strategies are effective, ADF may lead to greater weight loss in the short term (4). For their part, Ekberg et al. (15) demonstrated that the 5:2 protocol (a variation of the MADF that generally consists of five days of normal eating and two nonconsecutive days of modified fasting or very low-calorie intake) was effective in people with type 2 diabetes, resulting in improvements in insulin sensitivity in subjects without diabetes. This led the authors to validate the 5:2 diet as a viable and effective intervention for managing overweight in both patient groups (15), suggesting that ADF/MADF can be adapted to different clinical profiles.

Despite these positive findings, questions remain as to whether the effects are due to the timing pattern itself or to the total calorie reduction, which is not always controlled. Furthermore, the physiological mechanisms underlying its effect on insulin sensitivity or visceral fat are not yet fully understood. In terms of tolerability, the ADF may present practical challenges due to its alternation between restriction days and free-eating days, which could affect long-term adherence. The available evidence on its impact on eating behavior, satiety, or mood is still limited, making it difficult to assess its sustainability outside of controlled settings.

As far as the MADF (5:2 protocol) is concerned, the evidence is mixed. Keenan et al. (8) and Pannen et al. (14) They compared it to continuous calorie restriction (CCR). Although Keenan et al. (8) reported greater reductions in total cholesterol and LDL, noting that both strategies were well tolerated (8); the study by Pannen et al. (14) (with a follow-up of 102 weeks) concluded that, although weight loss was similar to that achieved with RCC, adherence to the MADF was more difficult to maintain in the long term (14). This issue of sustainability is central. In addition, nutritional quality is a concern, as Scholtens et al. (13) noted that, although effective for weight loss, the 5:2 diet may lead to deficiencies in essential micronutrients such as calcium, zinc, and magnesium (13). Finally, Witjaksono et al. (12) found that, although the 5:2 diet promoted weight loss, it did not have a significant impact on body composition compared with the control group (12), casting doubt on its clinical relevance in that context.

Overall, the evidence suggests that ADF and MADF may be effective for weight loss, but there are concerns about their sustainability and safety. The methodological limitations in this group of studies are significant: the duration varies widely, ranging from 3 weeks in the study by Chair et al. (4) up to 102 weeks, according to Pannen et al. (14), which makes it nearly impossible to compare actual sustainability. The main challenge with these protocols is sustained adherence; although compliance rates in clinical trials exceed 80%, the evidence from Pannen et al. (14) suggests that this decreases dramatically in real-world contexts. Furthermore, assessments of overall nutritional status are scarce; the findings on micronutrient deficiencies reported by Scholtens et al. (13) is a warning sign that indicates the need for rigorous professional support. Therefore, both ADF and MADF should be approached with caution, requiring a patient-tailored approach and further long-term research to establish their role within a comprehensive nutritional approach.

Table 2 Studies on ADF and MADF fasting and a control group in individuals who are overweight, obese, and/or have early-stage metabolic syndrome.

Author, year	Study Design	Population	N (Sample)	Duration	Speech	Key Findings
Chair, et al. 2022. (4)	Randomized, controlled clinical trial.	Adults who are overweight or obese and have prediabetes	101 (in 3 groups)	3 weeks	ADF vs. RET (16:8) vs. Control	Weight loss, BMI, and waist circumference (ADF and RET vs. Control; $p < .05$). Greater weight loss and BMI reduction in the ADF group (vs. RET; $p < .001$). Improvements in glucose and triglycerides (vs. Control; $p < .05$).
Scholtens et al. 2020. (13)	Randomized clinical trial.	Overweight/obese adults (with and without T2DM)	38 (F=27, M=11)	6 weeks	MADF (5:2 Protocol)	A significant decrease in carbohydrate and fiber intake ($p < 0.001$). Micronutrient intake (Ca, Zn, Mg, K) is below the recommended levels.
Pannen et al. 2021 (14)	Randomized clinical trial.	Overweight or obese adults (ages 35–65)	98	12 weeks (follow-up at 102 weeks)	MADF vs. Classic Calorie Restriction (CCR)	Similar effectiveness in weight loss (MADF vs. RCC) at 2 years ($p = 0.63$). No significant differences in long-term dietary composition. (Worse adherence reported in MADF compared to RCC).
Keenan, et al. 2022 (8)	Randomized clinical trial.	Adults (F=17, M=17) with a BMI > 27.0 kg/m^2	34	12 weeks	MADF (5:2) vs. Classic Calorie Restriction (CCR)	A significant reduction in total cholesterol (TC; $p < 0.001$) and LDL-C ($p < 0.001$) was observed in both groups. Greater reduction in TC and LDL-C in the MADF group (vs. RCC). High adherence (~80%) was reported in both groups.
Witjaksono et al. 2022. (12)	An open-label, randomized, controlled clinical trial.	Participants (adults)	50 (AI=25, Control=25)	3 months	MADF (5:2 Protocol) vs. Control	Significant weight loss in the fasting group ($p = 0.023$). No significant changes in body composition (fat mass, lean mass) were observed between groups (vs. control; $p > 0.05$).
Ekberg et al. 2024. (15)	Non-randomized controlled clinical trial.	Adults with Type 2 Diabetes and controls without diabetes	97 (DBT=35, Control=62)	6 months (12-month follow-up)	MADF (5:2 Protocol)	Reduction in glucose (DBT2; $p<0.05$) and insulin (Control; $p<0.05$). Both groups: Improvements in C-peptide, HOMA-IR, waist circumference, BMI, and body fat percentage ($p<0.05$). Greater

						improvement in glucose and waist circumference in DBT2 (vs. Control; $p<0.05$).

As shown in Table 3, studies that evaluated intermittent fasting protocols with fasting periods longer than 24 hours reported improvements in body weight, total body fat, and cardiometabolic parameters (5,16,17). Although less commonly reported in the literature, these interventions could offer greater benefits in terms of certain indicators, although doubts remain about their long-term feasibility.

Arciero et al. (5) They compared the effectiveness of one versus two consecutive days of prolonged fasting per week, as part of a low-calorie, high-protein diet. Both approaches reduced weight, body fat, waist circumference, and blood pressure, although the group that fasted for two consecutive days (AI-2) showed significantly greater reductions in weight (-29%) and waist circumference (-38%). Furthermore, no increases in hunger or changes in appetite-related hormones (ghrelin, GLP-1) were observed, possibly due to an increase in ketone bodies, a diet rich in protein and fiber, and a possible modulation of the gut-brain axis. These findings reinforce the feasibility and good tolerability of prolonged fasting, even with a 40% calorie restriction.

In the study by Teong et al. (16) Overweight or obese women fasted for 24 hours three times a week, compared with continuous calorie restriction. The fasting group achieved greater weight and body fat loss, with no adverse effects on mood, sleep, cognition, or eating behavior. The inclusion of light breakfasts and low-calorie broths on fasting days, along with structured supervision, may have improved adherence. Despite the intensity of the protocol, the authors found no evidence of cognitive impairment, which supports its psychological safety in this population.

An interesting aspect of this study is that the assessments were also conducted on fasting days, which lends greater credibility to the findings, as it rules out possible transient effects of mental fatigue or immediate emotional changes during prolonged fasting. This suggests that, at least in the short term, overweight or obese women can maintain this type of routine without compromising their cognitive performance or emotional well-being.

Furthermore, the protocol's structure highlights the importance of practical intervention design. Allowing small amounts of food in the form of broths or light breakfasts, far from invalidating the concept of fasting, appears to have been a useful strategy for maintaining adherence without interfering with metabolic and body composition outcomes. This point opens the discussion on the flexibility that prolonged intermittent fasting protocols may offer and on how relatively small adjustments can make a difference in clinical feasibility.

Finally, Liu et al. (17) compared three strategies: 24-hour fasting three times a week with 70% (AI70) or 100% (AI100) of caloric needs on eating days, and continuous caloric restriction to 70% (CR70). The AI70 group showed greater weight and fat loss, as well as greater lipid mobilization (reduction in nonesterified fatty acids), but also exhibited decreased insulin sensitivity and lower expression of antioxidant enzymes, suggesting a possible adverse metabolic effect when sufficient intake is not achieved on feeding days.

Overall, the data support the effectiveness of prolonged intermittent fasting as a strategy for weight loss and cardiometabolic improvement. However, its effects on insulin sensitivity and oxidative stress raise questions about its safety, especially in overweight women. Furthermore, the short duration of the studies (4–8 weeks) limits the generalizability of the results. Future trials should address the long-term sustainability, tolerability, and safety of these protocols in various populations.

Table 3. Studies on PF Fasting and a control group in individuals who are overweight, obese, and/or have early-stage metabolic syndrome.

Author, year	Study Design	Population	N (Sample)	Duration	Speech	Key Findings
Arciero et al. 2022 (5)	Randomized controlled clinical trial.	Overweight Adults	20	4 weeks	1-Day Fast (AI-1) vs. 2-Day Fast (AI-2). (Both are high in protein.)	Significant reduction in weight, waist circumference, body fat percentage, and lipid levels in both groups (AI-1 and AI-2; $p < 0.05$). Greater reduction in weight (-29%) and waist circumference (-38%) in the AI-2 group (vs. AI-1; $p < 0.05$). A trend toward greater reductions in fat and glucose was observed in AI-2 ($p < 0.10$).
Teong, et al. 2021 (16)	Secondary analysis of a randomized controlled clinical trial.	Overweight or obese women (average age 50)	46	8 weeks	24-Hour Fasting (AI) vs. Classic Calorie Restriction (CCR). (Both at 70% of energy requirements.)	Greater weight and body fat loss in AI (vs. RCC; $p < .001$). No differences (vs. RCC) on eating behavior, mood, sleep, or quality of life ($p > .05$). No adverse effects on cognition or mood during fasting days ($p > .05$).
Liu et al. 2021 (17)	Secondary analysis of a randomized controlled clinical trial.	Women (BMI 25–40)	76 (in 3 groups)	8 weeks	CR70 (RCC 70%) vs. AI70 (24-hour fast 3 times a week, 70% calories) vs. AI100 (24-hour fast 3 times a week, 100% calories)	Greater weight and fat loss in AI70 (vs. RCC70/AI100; $p<0.05$). AI Groups: Significant reduction in antioxidant enzymes (vs. RCC70; $p<0.05$). 24-hour fast: Insulin sensitivity worsened ($p<0.05$).

Discussion of the Underlying Physiological Mechanisms

The consistent results regarding weight and fat mass reduction observed in most of the studies analyzed (6, 10, 16) are based on the profound metabolic changes induced by fasting. When food intake ceases, the body shifts from an anabolic state to a catabolic state in order to maintain energy homeostasis. Once liver glycogen stores are depleted (usually within the first 12–16 hours), the body activates a "metabolic switch," initiating a key transition from glucose utilization to the mobilization of fatty acids from adipose tissue.

This metabolic change triggers a cascade of physiological adaptations. Fasting promotes lipid catabolism to maintain blood glucose levels, and its benefits include the induction of ketogenesis, hormonal regulation (notably a reduction in basal insulin), a reduction in oxidative stress and inflammation, as well as increased stress resistance, and the activation of lipolysis and autophagy (3). The activation of lipolysis and the subsequent ketogenesis are the direct mechanisms that explain the reduction in fat mass reported in nearly all studies (5, 10, 16). At the same time, reducing oxidative stress and inflammation (3) is crucial to understanding improvements in cardiometabolic health. These mechanisms are consistent with the findings of Teong et al. (11) and Ekberg et al. (15), who reported significant improvements in glucose tolerance and insulin sensitivity, respectively.

It is important to note, however, that most of the clinical trials included in this review (Tables 1–3) did not directly measure these molecular mechanisms; they focused on anthropometric outcomes and standard biomarkers. Therefore, the connection between the mechanism (e.g., autophagy) and the outcome (e.g., weight loss) is inferred theoretically (3). Furthermore, the relationship is not always positive. The study by Liu et al. (17) serves as a reminder of this complexity, as its findings of reduced insulin sensitivity and lower expression of antioxidant enzymes in the AI70 group suggest that excessive restriction may, paradoxically, induce a state of adverse metabolic stress. This underscores that the physiological benefits of fasting are not linear and depend on the intensity of the protocol.

General Discussion of the Findings

An analysis of the 14 studies reviewed reveals that intermittent fasting, in its various forms, is an effective strategy for reducing body weight and improving body composition in people who are overweight, obese, or have early-stage metabolic syndrome. The most common protocols, such as the 16:8 intermittent fasting (6, 10) or alternate-day fasting (4), have shown significant reductions in body fat. In direct comparison with traditional continuous calorie restriction (CCR) diets, AI has been shown to be at least as effective (14), although some studies suggest greater fat loss (16) or superior metabolic benefits (11).

With regard to metabolic parameters, AI improves blood glucose levels, insulin resistance, and lipid profile, although these findings are more inconsistent than those related to weight loss. Studies such as those by Teong et al. (11) and Ekberg et al. (15) showed clear improvements in glycemic control. Others, such as Keenan et al. (8) reported reductions in LDL cholesterol. However, the extent of these effects varies across studies (6), and some even warn of potential metabolic risks (such as decreased insulin sensitivity in highly restrictive prolonged fasting regimens) (17). This suggests that the benefits of AI may depend heavily on the specific protocol and the individual's baseline metabolic state.

With regard to adherence, although AI is generally well tolerated, it is not without its challenges. Some individuals experience initial side effects such as fatigue, headache, or irritability (11), although these are usually temporary. Long-term sustainability is the real challenge: more flexible protocols such as RET 16:8 appear to have high adherence (9), while more restrictive protocols such as MADF 5:2 have shown declining adherence in long-term follow-ups (14). The available evidence suggests that flexibility, professional supervision, and a gradual adjustment process are key to promoting continuity over time.

When comparing the different types of intermittent fasting analyzed, all of them show positive effects on weight loss. The RET pattern (especially 16:8) stands out for its balance between effectiveness and sustainability, making it likely the most viable option for initial clinical practice. The ADF/MADF (5:2 Protocol) appears to lead to greater short-term weight loss (4) and improvements in insulin sensitivity (15), but at the cost of potentially lower long-term adherence (14) and nutritional risks (13). Finally, prolonged fasting (>24 hours) shows great potential (5), but the evidence regarding its safety and clinical efficacy is still limited and presents conflicting results (17).

Conclusions and Future Implications

This narrative review confirms that intermittent fasting (IF), in its various forms (RET, ADF/MADF, and prolonged fasting), is an effective nutritional intervention strategy for reducing body weight and improving body composition in overweight and obese adults. The findings from the 14 clinical trials analyzed suggest that its benefits are, at a minimum, comparable to continuous calorie restriction (CCR) (11, 14), and for certain parameters—such as fat loss (16) or improved glucose tolerance (11)—they may even be superior. However, the main advantage of AI does not appear to be universal metabolic superiority, but rather its potential as a viable alternative that can improve adherence in patients for whom RCC has failed. The success of the procedure does not lie in a single protocol, but rather in its customization. The implementation should be tailored to the patient's individual characteristics, baseline metabolic status (15), and lifestyle. Essentially, this strategy should always be implemented under professional supervision in order to optimize adherence and reduce risks (such as fatigue or headaches, as reported by Teong et al. (11)) and monitor nutritional quality to prevent micronutrient deficiencies (13) or adverse metabolic effects (17).

It is essential, however, to put the scope of this review into context. The study design, which focuses on a qualitative synthesis, means that the selection of 14 articles—while intentionally representative of AI modalities—is not exhaustive. This can introduce selection bias by prioritizing certain findings over others, potentially overlooking studies with null or contradictory results. Furthermore, the search methodology has its own limitations: since it is restricted to the PubMed database (supplemented by Google Scholar) and the English language, it is possible that relevant research from other regions or in other languages may have been excluded. An additional limitation is the absence of a formal assessment of the methodological quality (e.g., risk of bias) of each trial. For this reason, studies with less methodologically robust designs (e.g., non-randomized) are discussed alongside controlled trials, and the findings should be interpreted as an analysis of the current landscape, not as a quantitative meta-analysis.

Finally, to strengthen the available evidence, future research should address the limitations identified here. It is imperative to conduct randomized controlled trials with larger and more diverse samples that include different age and ethnic groups. The duration of the studies is the most critical factor; long-term follow-up (>1 year) is needed to assess the actual sustainability of adherence, a weakness identified in protocols such

as the MADF (14). Beyond weight, future research should systematically assess the impact on nutritional quality (addressing the micronutrient risks identified in Scholtens et al. (13)), bone health, and metabolic safety, especially during prolonged fasting (given the findings of Liu et al. (17) on insulin sensitivity). In addition, more research is needed on the long-term impact of AI on mental health, sleep quality, and eating behavior—aspects that Teong et al. (16) They only measured short-term effects. Another under-explored area is the cost-effectiveness analysis of AI compared with RCC or pharmacological treatments for obesity. Furthermore, it is essential to establish standardized intervention protocols and conduct direct comparisons with RCC in non-inferiority trials in order to more clearly define the advantages and limitations of intermittent fasting as a therapeutic tool in clinical practice.

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Description of risky eating habits and behaviors among adolescents at a university in Guanajuato

Descripción de los hábitos y conductas alimentarias de riesgo en adolescentes de una universidad en Guanajuato

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ABSTRACT

In recent times, there has been an increase in malnutrition rates, a situation that, among other populations, is having a worrying effect on adolescents, making it necessary to analyze the possible causes of this increasingly intense trend. Consequently, the general objective of the study is to evaluate eating habits and disorders in 16- and 17-year-old students in upper secondary education at the University of Guanajuato. A descriptive research design was used, with a random probability sample of 241 students, who were given a questionnaire on food consumption frequency, considering the healthy eating index (IAS), as well as a questionnaire on risk behaviors (CAR) to assess eating habits and disorders, respectively. The information obtained was statistically processed using response percentages. The results of the research indicate that 28.5% report a healthy and varied diet, and 37.7% comply with daily consumption recommendations. Regarding students' eating behaviors, 16% were found to be at high risk of developing eating disorders. Therefore, it can be concluded that students' diets require changes in terms of frequency and variety. Furthermore, there are practices that students engage in that make them susceptible to developing eating disorders (TCA), which requires the necessary intervention and measures within the institution for the corresponding prevention and care, for the benefit of the present and future health of students.

Palabras clave:
Alimentación, Hábitos, Conductas, Estudiantes.

RESUMEN

En los últimos tiempos ha existido un incremento en los índices de malnutrición, situación que, entre otras poblaciones, afecta de manera preocupante a los adolescentes, por lo que se hace necesario el analizar las posibles causas de esta tendencia que cada vez se manifiesta con mayor intensidad, derivado de ello, el objetivo general del estudio es evaluar hábitos y trastornos del comportamiento alimentario, en estudiantes de 16 y 17 años del nivel medio superior de la universidad de

	Guanajuato. Se realiza una investigación descriptiva, con una muestra probabilística aleatoria de 241 estudiantes, a quienes se aplica el cuestionario de frecuencia de consumo de alimentos, considerando el índice de alimentación saludable (IAS), así como el cuestionario de conductas de riesgo (CAR) para evaluar hábitos y trastornos alimentarios respectivamente, la información obtenida es tratada estadísticamente mediante porcentajes de respuesta. Los resultados de la investigación indican que el 28,5% manifiesta una alimentación saludable y variada, y el 37,7% cumple con las recomendaciones de consumo diario. En cuanto a las conductas alimentarias de los estudiantes, el 16% se encontró en riesgo alto de desarrollar trastornos de la conducta alimentaria. Por lo anterior se concluye que la alimentación de los alumnos requiere de modificaciones en cuanto a frecuencia y variedad, por otra parte, existen prácticas que los estudiantes realizan y que son susceptibles para desarrollar trastornos de la conducta alimentaria (TCA), lo cual requiere de la intervención y gestiones necesarias al interior de la institución, para la intervención de prevención y atención correspondiente, en beneficio de la salud presente y futura de los estudiantes.

Introduction

Eating habits and behaviors are repetitive practices related to the selection, preparation, and consumption of food. These habits are influenced by several factors, including economic considerations, which affect the availability and affordability of certain types of food—a situation that disproportionately impacts the most vulnerable populations, who sometimes opt to purchase and consume foods that are high in calories but low in nutritional value (1).

With reference to the psychological realm as a motivating factor for habits and behaviors, and considering that adolescence is marked by emotional episodes triggered by various causes, at this stage, adolescents are faced with situations that require them to find their own solutions, fostering a sense of individual responsibility. This can create environments of stress and anxiety that may lead to emotional imbalance, with the potential emergence of eating disorders that can become habits (2).

Lifestyles are another factor to consider in the acquisition, practice, or development of eating habits and behaviors, noting that if they are not beneficial to health, they will have immediate or future repercussions. Among these unhealthy lifestyles are drug use, lack of rest, the accumulation of emotional stress, a lack of regular physical activity, and, of course, a diet that is not nutritious and does not meet personal needs (3).

Another factor is the family environment, as it plays a role in the acquisition or development of eating behaviors; in many cases, adolescents are dependent on the decisions of their parents or guardians, which influence their current and future attitudes and may, in turn, affect the quality of their diet (4). Regarding the importance of family influence, the World Health Organization (WHO) (5) stated in 2017 that the nuclear family plays a crucial role in establishing healthy eating habits from an early age, which promote healthy and adequate growth, support proper development, and contribute to cognitive improvement, in addition to the health benefits these habits foster in the short, medium, and long term throughout a person's life.

The media is another factor to consider at this stage of life in terms of the development of eating habits and behaviors. Advertising promotes beauty stereotypes, and failure to meet these standards can lead to frustration in adolescents, which in turn can affect the development of eating habits and behaviors that impact their physical, psychological, and emotional health (6).

Another factor that influences eating behaviors is the adolescent's own understanding of the concept of healthy eating, which is shaped by their life experiences, knowledge of the subject, tastes, preferences, access to food, portion sizes, preparation methods, frequency, and mealtimes, as noted by Robledo et al. (7) (2023) mentions in their study that students are aware that a varied diet is beneficial to health and that fast food, soft drinks, and sugar, although they enjoy them, they recognize that they are not good for their health, reiterating that one's construct of healthy eating influences decision-making and, consequently, the manifestation of eating habits and behaviors.

Equally important is the fact that students' limited or nonexistent connection to support groups—such as their own families, educational institutions, and health care providers—is another risk factor for the development of unhealthy habits and behaviors. This lack of connection prevents students from receiving the guidance and training they

need to make their own decisions about food and nutrition, while always prioritizing self-care (8).

The repercussions of adopting unhealthy eating habits and risky eating behaviors are felt worldwide. In this regard, as stated by the WHO (9), in 2022 there were 390 million overweight children and adolescents, of whom 160 million were obese. In this regard, it is stated that "Poor nutrition causes serious harm to the health and development of children and adolescents: increased morbidity and mortality, impaired cognitive function and lower academic performance, stigma and discrimination, as well as chronic diseases, premature mortality, and a lower quality of life in adulthood" (10).

These dietary habits and behaviors represent a deeply concerning situation that requires immediate attention due to the nature and consequences of diseases, including metabolic changes such as high blood pressure, insulin resistance leading to elevated serum glucose levels, atherosclerosis, decreased levels of high-density lipoproteins (HDL), increased levels of low-density lipoproteins (LDL), and obesity (11).

These conditions are closely linked to lifestyle; therefore, it is essential to pay special attention to the development of eating habits and behaviors at an early age, so as to establish the necessary conditions for promoting, developing, and maintaining good health by reducing current and future risks of chronic degenerative diseases, thereby enabling individuals to positively influence their quality of life (12). According to Galván (13), the term "quality of life" refers to the fulfillment of physiological, economic, social, material, and emotional needs; therefore, the concept includes both objective and subjective factors aimed at individual well-being. Consequently, it is related to achieving a state of good physical and mental health, as well as the attainment of personal goals.

With regard to health care, Bustamante et al. note that (14) Adolescence is the stage of transition from childhood to young adulthood, during which childhood behaviors and attitudes are gradually abandoned or undergo gradual changes, as the individual adopts behaviors characteristic of a young person preparing for adulthood. During this period, highly noticeable changes occur in a person—ranging from their morphological structure and physiological adaptations to their decision-making abilities—which influence their personality traits and quality of life.

A defining feature of adolescence is the ability to develop, construct, and express one's identity. To achieve this, individuals go through drastic behavioral changes ranging from anxiety to the choice and execution of actions. In this process, society exerts a significant influence on decision-making, which is why self-perception and body image pose a real challenge at this stage of life (15). The concept of self-image refers to the mental representation and expression that a person constructs of their own body; it is the way they perceive themselves, how they feel, and, consequently, how they act based on that perception. Self-image can change over the course of one's life, with adolescence being the stage when individuals are most vulnerable in terms of body acceptance due to the various changes that occur during this period, which can lead to either acceptance or rejection of one's own image (16). In this process, as Zúñiga (17) notes, self-esteem is particularly important, since a high percentage of this population harbors prejudices regarding their physical appearance, which either facilitates their adaptation to a social group or, conversely, leads to psycho-emotional distress, causing this to interfere with the adolescent's daily activities and giving rise to the onset or development of eating habits and behaviors that may benefit or harm their health.

Among the consequences of adopting unhealthy eating habits and risky behaviors are weight gain due to excessive consumption of high-calorie foods and unhealthy fats, and low or no consumption of fruits, vegetables, and fiber-rich foods—a situation that can sometimes have fatal consequences (18).

Similarly, significant hormonal changes occur, such as an increase in ghrelin levels, which leads to increased appetite, and a decrease in leptin levels—a hormone that regulates appetite—thereby increasing caloric intake and raising the risk of overweight and/or obesity in adolescents (19).

Due to poor eating habits, the global adolescent population has seen a 28% increase in the rates of overweight and obesity compared to 2016; in Latin America, this nutritional issue is considered a critical health situation due to the alarming rates being reported. Specifically in Mexico, it is estimated that more than 80% of this population is at latent risk of becoming obese adults, with the health consequences that this condition entails (20). In this regard, Mexico is cited as one of the countries with the highest rates of this condition, with one in three adolescents being obese or overweight; therefore, it is necessary to accurately identify the contributing factors in order to establish concrete strategies to address this health issue, both now and in the future (21).

The issue addressed in this study concerns the growing trend of malnutrition and eating disorders among adolescents nationwide, as reported by the National Health and Nutrition Survey, which indicates that 40.4% were overweight or obese. This represented a 26.8% increase compared to 1999. Currently, overweight and obesity among adolescents are the most prevalent conditions that prevent them from adopting and maintaining healthy lifestyles (22).

Given the above, the objective of this study was to evaluate risky eating habits and behaviors among 16- and 17-year-old high school students.

Method

Study Type

The study was quantitative, descriptive, and cross-sectional.

Participants

The institution where the research is being conducted is the Guanajuato High School (ENMSG), which opened in 1971 to provide a general high school education to the population of Guanajuato City. It is one of the first choices for students in the municipality who have completed their basic education and wish to continue their studies at this level.

The ENMSG currently has an enrollment of 880 students in the afternoon session. The participants were students at that educational level; 640 students were considered for a random probability sample. A 95% confidence level and a 5% margin of error were used, resulting in a sample size of 241 students.

To this end, the following inclusion criteria were applied: students aged 16 to 17, enrolled in the afternoon session, currently in their 2nd and 4th semesters, and who agreed to participate in the study.

The exclusion criteria include: students who are 15 or 18 years old; students enrolled in the 1st, 5th, or 6th semester of high school; students enrolled in the morning session; as well as those who do not agree to participate in the study or decide to withdraw from it.

Technique

Two questionnaires were administered to gather information on risky eating habits and behaviors, respectively. The instruments used for data collection were: the food frequency questionnaire, which provides insight into compliance with daily, weekly, and occasional recommendations, as well as dietary variety, based on the Healthy Eating Index (HEI). This questionnaire contains 10 variables, which are specified in the following structure:

1. Consumption of grains and grain products.
2. Consumption of vegetables.
3. Fruit consumption.
4. Consumption of milk and dairy products
5. Meat consumption
6. Consumption of legumes
7. Consumption of sausages and cold cuts.
8. Eating sweets.
9. Consumption of sugary soft drinks
10. Dietary Variety

Based on the dietary guidelines recommended by the Spanish Society of Community Nutrition (SENC), variables 1, 2, 3, and 4 represent foods consumed daily, such as grains and grain products, vegetables, fruits, milk, and dairy products; variables 5 and 6 represent foods for weekly consumption (1 to 2 times a week), including meats and legumes, while variables 7, 8, and 9 refer to foods for occasional consumption (never or almost never), such as processed meats and cold cuts, sweets, and sugary soft drinks. Point 10 determines the variety of the diet.

This questionnaire awards a maximum of 10 points when the consumption frequencies recommended by the SENC are followed, with scores awarded in descending order of 7.5, 5, 2.5, and a minimum of zero points if these recommendations are not followed. With regard to the variety of the diet, 2 points are awarded for meeting the daily frequency recommendations and 1 point for following the weekly suggestions (23).

The Risky Eating Behaviors Questionnaire (CAR) was also used; based on the responses provided, it identified potential behavioral abnormalities related to eating that could pose a risk for the development of eating disorders. It addresses issues such as fear of gaining weight, binge eating, lack of control over eating, and restrictive and purgative eating behaviors. This questionnaire has four response options, scored on a scale from 0 to 3, where 0 represents “never or almost never” and 3 represents “very often” (24).

Results

The sample consisted of 241 students, 223 of whom completed the questionnaires designed to assess their eating habits and risky eating behaviors.

As shown in Table 1, based on the IAS recommendations, 28.5% of the students reported having a "HEALTHY AND VARIED DIET" that met the suggested criteria. In terms of the frequency and variety of foods consumed, 32.6% fell into the "NEEDS CHANGES" category, and 38.9%—according to the results—were rated as having a "LESS HEALTHY" diet because they did not meet the recommended frequency and variety of foods.

Based on the IAS index recommendations, on average only 37.7% of students met the daily consumption recommendations, while 21.5% followed the weekly consumption recommendations, and 21% followed the occasional consumption recommendations.

According to the data, the most frequently consumed foods in the "healthy eating" category are fruits and legumes, while those consumed in smaller quantities include grains and grain products, meat, and sugary soft drinks. As for the foods most commonly consumed in the "unhealthy" category, these include vegetables, fruits, legumes, and sugary soft drinks. In this same category—grains and grain products, meats, sausages, and cold cuts—these are the foods that are consumed the least

Table 1. Dietary Characteristics Based on Results.

Variables **Daily intake**	**Daily intake 10 points**	**I consume it 3 or more times a week, but not every day 7.5 points**	**Consumed 1 to 2 times a week 5 points**	**I consume it less than once a week—2.5 points**	**Food consumption: never or almost never—score 0**
1. Grains and grain products	18%	38%	30%	9%	5%
2. Vegetables	39%	38%	18%	4%	1%
3. Fruits	52%	32%	12%	3%	1%
4. Milk and dairy products	42%	28%	22%	4%	4%
Weekly consumption	Consumed 1 to 2 times a week			Daily intake	Daily intake
5. Meat	11%	52%	1%	33%	3%
6. Legumes	32%	47%	9%	10%	2%
Occasional consumption	Never or almost never	I eat it less than once a week	I eat it less than once a week	I consume it 3 or more times a week, but not every day	Daily intake
7. Sausages and cold cuts	22%	22%	38%	15%	3%
8. Sweets	12%	21%	33%	28%	6%

9. Sugary soft drinks	29%	15%	23%	24%	9%
	10. Variety: **2 points if you meet each of the daily recommendations.** **1 point if you follow each of the weekly recommendations**				
Variety	2	1	0	0	0
Total score	92	68.5	45	22.5	0
Feeding category (Norte and Ortiz, 2011)	**HEALTHY 28.5%**	**CHANGES ARE NEEDED 32.6%**	**NOT VERY HEALTHY 20.7%**	**NOT VERY HEALTHY 14.5%**	**NOT VERY HEALTHY 3.7%**
Most Commonly Consumed Foods	Fruits, vegetables	Grains and grain products, vegetables, meat, sugary soft drinks	Grains and grain products, legumes, sugary soft drinks	Grains and grain products, meats, sausages, and cold cuts	Vegetables, fruits, legumes, soft drinks
Foods Consumed Least Often	Grains and grain products, meat, sugary soft drinks	Milk and dairy products, legumes, sausages, and cold cuts	Fruit, meat, sausages, and cold cuts	Fruits, vegetables, sweets	Grains and grain products, meats, sausages, and cold cuts

Regarding the Risky Eating Behaviors Questionnaire (CAR), as shown in Table 2. Among the activities identified as posing the highest risk for developing an eating disorder, 46% mentioned exercising with the intention of losing weight, followed by 38% who expressed concern about gaining weight and 27% who reported that they have sometimes overeaten; 15% report having lost control over what they eat (a feeling of being unable to stop eating), 13% report having gone on diets, and 10% report having fasted for 12 hours or more; these last two percentages were done with the goal of trying to lose weight.

With regard to activities performed less frequently and posing a lower risk for the development of eating disorders, the report indicates that 2% of students have taken laxatives to facilitate bowel movements, 3% report having used pills, in both cases, the students did not specify what types of substances they consumed; meanwhile, 5% reported having vomited after eating, and finally, 4% mentioned having taken diuretics. In all of these less frequently engaged-in activities, the goal is to try to lose weight.

Table 2: Responses to the CAR Screening Questionnaire

	Never or almost never	**Sometimes**	**Frequently: twice a week**	**Very often: more than twice a week**
I've been worried about gaining weight	26%	36%	15%	23%
Sometimes I've eaten too much; I've stuffed myself.	24%	49%	14%	13%
I've lost control over what I eat (I feel like I can't stop eating).	54%	31%	8%	7%

I've been throwing up after meals to try to lose weight	87%	8%	3%	2%
I've fasted (going without food for 12 hours or more) to try to lose weight.	66%	24%	5%	5%
I've been on diets to try to lose weight	60%	27%	10%	3%
I've been exercising to try to lose weight.	26%	28%	22%	24%
I've used pills to try to lose weight. Specify which one(s)	94%	3%	2%	1%
I've been taking diuretics (medication to help eliminate water) to try to lose weight. Specify which one(s)	93%	3%	2%	2%
I've been taking laxatives (a substance that helps with bowel movements) to try to lose weight. Specify which one(s)	91%	7%	1%	1%

Figure 1 shows the percentage of risk for developing eating disorders, indicating that a score of 11 or higher indicates a risk of developing these behaviors, a score of 7 to 10 is considered moderate risk, and a score of less than 7 indicates no risk of developing them (Unikel et al. (2011).

With regard to the situations described by the students three months prior to completing the Risky Eating Behaviors Questionnaire (CAR), it was determined that 62% did not show a risk of developing eating disorders, 22% were at moderate risk, and 16% were at high risk of developing eating disorders.

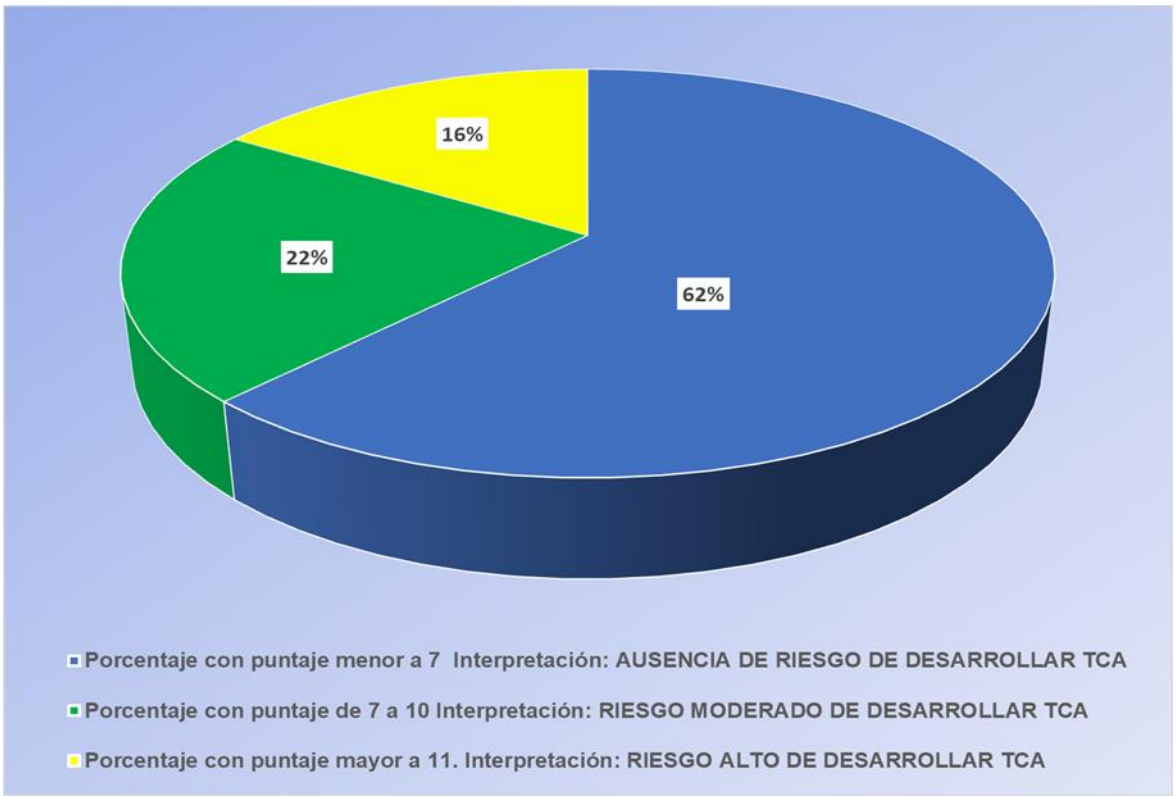

Figure 1. Percentages of risk of developing an eating disorder.

Discussion and Conclusions

The research findings show that the diets of 71% of the students in the study require changes to promote healthy eating, in terms of recommended daily intake, weekly, and occasional intake. The data indicates a limited variety in dietary intake; consequently, their dietary status does not meet the requirements for promoting or maintaining optimal health, as defined by the IAS.

The results presented here are similar to those reported in the study by Aguilera et al. (25) which analyzed the lifestyles of students in the Sabana Centro province of Cundinamarca, Colombia, with regard to eating habits and behaviors, concluding that these were not adequate, as the students consistently consumed fast food and drank large amounts of carbonated beverages.

The findings of this study are consistent with the results of the study by Ruiz and Aguilera (26), which evaluated dietary habits at the Institución Universitaria Colegios de Colombia. The study found that these habits are not ideal, as there is a lack of dietary variety, carbohydrate intake is high, and protein consumption is low, noting that 75% of the participants have an unhealthy diet.

Furthermore, the results are consistent with the research by Maza et al. (27) In which a literature review was conducted; this review noted that findings published in specific health sciences journals indicated that 87.72% of college students engage in unhealthy habits, as evidenced by a diet lacking in variety and of low nutritional quality.

With regard to eating behaviors, while it is true that the findings of this study indicate that only 38% pose a risk of developing an eating disorder, given the nature and significance of these behaviors, it is necessary to implement the necessary measures to eradicate them, with the goal of ensuring that the student population is free of eating habits that are harmful to health.

The findings presented here are consistent with the study conducted by Saucedo et al. (28) which identified the presence of risky eating behaviors among high school students and concluded that 15.5% were at high risk, while 17.3% were at moderate risk.

In contrast to the work by Bautista et al. (29) which analyzed 200 Mexican high school students and reported that only 5.5% exhibited risky eating behaviors and 94.5% were not at risk for risky eating behaviors; these findings are consistent with the research by Villalobos et al. (30) whose objective was to report and update information regarding the prevalence of risky eating behaviors among Mexican adolescents, for which the results of the national health survey conducted in 2022 were considered; these results indicate that 6.5% report risky eating behaviors, while 93.5% do not exhibit risky eating behaviors. The information in these studies differs from that presented in the study itself, as the latter reports higher percentages of students at risk.

A close similarity is evident when comparing the results of this study with the study conducted by Sáez et al. (31) which analyzed risky eating behaviors among young adults in Chile in the municipalities of Chillán, and found that 37.16% are at risk for eating disorders, while 62.84% are not at risk.

Disclosing personal information sometimes makes it difficult to obtain such data, as it constitutes an invasion of the privacy of the research subjects. This situation is exacerbated when the information pertains to ways of thinking, actions, and behaviors that, in the subjects' view, may or may not be accepted by society; consequently, they prefer to conceal the truth or exclude themselves from the research, which poses an obstacle to the study's completion. In this study, 18 students chose of their own accord not to complete the questionnaires, a decision that was respected.

As a conclusion to this study, it is evident that the diets of the students in the study are unhealthy and need to be changed, specifically in terms of the frequency and variety of their food intake. With regard to eating disorders, certain behaviors have been identified among students, such as exercising because they feel they do not have the "ideal" body type, overeating, and fasting to lose weight—all of which are risk factors for the development of eating disorders.

The habits and behaviors described here indicate the need for professional intervention to address the situation outlined, with the aim of promoting or improving overall health, with a particular focus on eating habits and behaviors. It is important to recognize that unhealthy eating habits, combined with a poor diet, can lead to health problems among students, such as abnormal cholesterol and triglyceride levels and high blood pressure, as well as being overweight, obesity, malnutrition, cardiovascular disease, and psychological disorders.

As mentioned earlier, adolescence is a stage with very distinctive characteristics in terms of developmental, energy, physical, social, and psychological needs—a time when habits and behaviors in general become established and will shape behavior in adulthood. For this reason, it is essential that students receive the necessary support to foster eating habits and behaviors that promote these processes.

In light of the above, it is recommended that education and health authorities work together to develop and implement a nutritional assessment and intervention program, taking into account the specific characteristics and needs of students, thereby fostering healthy environments with regard to eating habits and behaviors. It is also recommended that relevant prevention and care measures be implemented, such as management, counseling, and training regarding food procurement, storage, preparation, and consumption, involving students, parents, and health institutions, thereby creating collaborative networks that promote, improve, and/or strengthen eating habits and behaviors to enhance current and future health.

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Conflict of Interest

I hereby declare, under penalty of perjury, that I have no conflict of interest in any activities that could introduce bias into the design, conduct, and/or results of this research.

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Nutritional supplementation for recovery from excersice-induced muscle damage: omega-3 fatty acids, curcumin and collagen

Suplementación nutricional para la recuperación del daño muscular inducido por el ejercicio: ácidos grasos omega-3, curcumina y colágeno

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ABSTRACT

Introduction: Nutritional supplementation for recovery from exercise-induced muscle damage: omega-3 fatty acids, curcumin, and collagen. Methodology: A bibliographic review was conducted, incorporating 15 clinical trials for detailed discussion, as well as systematic reviews and meta-analyses for contextual background. Studies were selected if they involved one of the target supplements alongside a standardized exercise protocol to induce muscle damage. Except for specific exceptions, all trials reviewed were published within the las five years and exclusively enrolled in humans. Results: Longer interventions with higher omega-3 doses consistently attenuated EIDM, whereas lower and shorter doses did not yield significant benefits. Curcumin supplementation failed to produce positive changes in inflammatory or muscle damage biomarkers. Finally, extended collagen supplementation reduced perceived muscle soreness and decreased muscle damage biomarkers. The marked heterogeneity in dosing, study duration and exercise protocols highlight de imperative for future research employing standardized methodologies. Discussion The current evidence is mixed, not allowing clinical recommendations to be made. Further randomized, placebo-controlled clinical trials with larger, more diverse sample space and rigorous design are needed to establish clear guidelines on the effectiveness of these supplements in mitigating EIMD.

Keywords:
Sports supplementation, muscle soreness, muscle injury, inflammation, tissue recovery.

RESUMEN

Introducción: Evaluar la eficacia de la suplementación con omega-3, curcumina y colágeno sobre la recuperación del daño muscular inducido por el ejercicio. Metodología: Se realizó una revisión bibliográfica de 15 ensayos clínicos para la discusión, además de revisiones sistemáticas y metaanálisis para la contextualización del tema. Para el análisis de estudios, se tuvieron en cuenta aquellos que involucrasen los suplementos mencionados y una pauta deportiva para inducir el daño muscular. Salvo excepciones puntuales, los ensayos analizados tienen un máximo de cinco años de antigüedad y están únicamente realizados en humanos. Resultados: Las intervenciones prolongadas con dosis más altas de N-3 afectaron positivamente al EIMD, mientras que dosis más pequeñas y durante

Palabras clave:
Suplementación deportiva, daño muscular, lesión muscular, inflamación, recuperación tisular.

periodos más cortos no mostraron esos efectos. La suplementación con curcumina no modificó de manera significative ni los marcadores inflamatorios ni los relacionados con el daño muscular. Finalmente, la suplementación con colágeno prolongada atenuó la percepción del dolor y redujo los biomarcadores de dolor muscular. La heterogeneidad de las dosis, duración y protocolos reafirma la necesidad de estudios futuros con metodologías estandarizadas. Discusión: La evidencia actual es mixta, no permitiendo realizar recomendaciones clínicas definitivas. Se requieren más estudios, con mayor espacio muestral y menos sesgados para definir pautas sólidas sobre la efectividad o no de los distintos suplementos evaluados.

Introduction

Exercise-induced muscle damage (EIMD) manifests with symptoms that may appear immediately after exercise and last up to fourteen days (1). Sports-related muscle injuries are a complex area of study, as they involve multiple factors such as gender, age, nutritional status, physical fitness, and genetics (2). In particular, DMIE usually occurs after movements to which the body is not accustomed, especially if they involve eccentric contractions (3). These injuries affect the musculoskeletal system and are associated with a loss of muscle mass and strength (4). In this context, nutrition plays a key role, as it can modulate inflammation and promote tissue regeneration (5).

The first report on the relationship between exercise and oxidative stress in humans was published more than four decades ago (6). In addition, muscle damage triggers an inflammatory response, as evidenced by swelling, decreased range of motion, and pain (7). Most studies reporting the discovery of dietary patterns with anti-inflammatory properties have been conducted in laboratories or on animals (8), so determining the effectiveness of nutritional ergogenic aids with antioxidant and anti-inflammatory properties could be of interest in terms of slightly modulating DMIE.

This topic is particularly relevant not only to health and physical performance, but also to understanding how certain supplements can influence recovery from exercise-induced muscle damage. Determining whether they are ergogenic and how to use them based on individual goals can be key to the success of nutritional interventions (9). An appropriate strategy could accelerate the recovery of musculoskeletal tissue, reduce the impact of the injury, and shorten the time it takes to return to activity.

According to the WHO, musculoskeletal disorders comprise more than 150 conditions that affect the musculoskeletal system, ranging from sudden, short-term injuries—such as fractures, sprains, and strains—to chronic conditions that cause permanent functional limitations and disability (10).

Musculoskeletal injuries are an inevitable part of every stage of human life, and they are exacerbated by lifestyle factors. Musculoskeletal injuries are very common among athletes during training or competition, resulting in lost time and time away from sports (11). Injuries among high-performance athletes are extremely common, affecting approximately 91.6% of athletes over the course of a year, with an average of 4.1 injuries per 1,000 hours of athletic activity (12). It is estimated that between three and five million sports-related injuries occur each year (13). On the other hand, lifestyle factors—such as progressive joint wear and tear and loss of muscle mass, which are sometimes the result of a sedentary lifestyle and poor nutrition—are catalysts for the onset of these types of problems (14). In both cases, the onset of this medical condition has a negative impact on the individual's independence, limiting their ability to work, play sports, or even perform everyday activities such as walking or getting up (15).

The recovery from damage to skeletal muscle follows a specific healing sequence, regardless of the cause of the injury. The first phase involves the rupture and subsequent necrosis of muscle cells. During the second phase, phagocytosis of the necrotic tissue occurs, along with the regeneration of myofibrillar tissue and the formation of connective scar tissue. Finally, the third and final phase is a period of maturation of the regenerated

myofibrils, contraction and reorganization of the scar tissue, and recovery of muscle tissue function (16)

Understanding the underlying mechanisms involved in the onset and progression of lesions, as well as their relationship to nutritional supplementation, is essential for developing strategies that promote the regeneration of affected tissues.

Engaging in a sport that an athlete is not accustomed to, as well as strenuous, high-intensity, or long-duration exercise, are several factors that can lead to muscle damage. DMIE is characterized by a primary response resulting from mechanical stress that occurs during exercise, as well as a secondary inflammatory response. Excessive stretching and the resulting disruption of the sarcomeres, followed by an increase in Ca2+ influx into muscle cells, result in passive muscle tension, causing myofibrillar disruption. These responses subsequently trigger secondary inflammatory responses, including the production of reactive oxygen species (ROS) and pro-inflammatory cytokines (17).

Delayed-onset muscle soreness is a common experience among athletes, whether they are beginners or experienced. Symptoms range from muscle tenderness to severe pain. The most common times when cases of DMIT occur are at the start of the sports season, when athletes return to training after a period of reduced activity. It is also common when athletes first take up certain activities, regardless of the time of year (18).

As Diego Fernández-Lázaro points out, there is a link between oxidative stress, inflammation, and muscle damage, since oxidative stress can lead to muscle damage. Inflammatory cells can promote oxidative stress by releasing enzymes (neutral proteases, elastase, collagenase, acid hydrolases), reactive species (superoxide, hydrogen peroxide, hydroxyl radical, hypochlorous acid, nitric oxide), and extracellular messengers (cytokines and interleukins). Taken together, these compounds can exacerbate inflammation and muscle damage (19). Immediately after a muscle injury occurs, the inflammatory response initiates tissue repair and regeneration by stimulating the release of pro-inflammatory cytokines, such as interleukin-6 (IL-6), interleukin-1β (IL-1β), and tumor necrosis factor-alpha (TNF-α). Pro-inflammatory cytokines act on the liver, stimulating the production and release of C-reactive protein (CRP), a marker of acute systemic inflammation (20).

DMIE is associated with increased serum levels of muscle enzymes, such as creatine kinase, lactate dehydrogenase, and myoglobin, as well as decreased strength and neuromuscular deficits (21). One of the links between omega-3 fatty acids and muscle inflammation lies in the regulation of pro-inflammatory cytokines, such as TNF-α and IL-6, which decrease the production of arachidonic acid (AA) and reactive oxygen species (ROS), thereby reducing the inflammatory response. Furthermore, creatine kinase (CK) is a marker of muscle damage, thus establishing its relationship with TNF-α and IL-6 (22)

Two mechanisms have been proposed through which omega-3 (N-3) fatty acids might affect DMIE and promote tissue repair. The first theory holds that N-3s circulating in the blood are absorbed by muscle and incorporated into the phospholipid bilayer, where—due to their cis-configuration carbon-carbon double bonds—they increase membrane fluidity and resistance to mechanical stress, thereby reducing damage caused by applied tension, preserving the structure of muscle fibers, and mitigating DMIE. In addition, N-3 promotes muscle repair through its anti-inflammatory properties. The incorporation of N-3 into the phospholipid bilayer of muscle occurs at the expense of omega-6 fatty acids,

which constitute the main substrate for the signaling pathways that regulate the production of eicosanoids, a process catalyzed by the enzymes cyclooxygenase and lipoxygenase. The signaling cascade reduces the formation of pro-inflammatory lipid mediators (prostaglandin E2, leukotriene B4) and increases the production of lipid mediators with low pro-inflammatory potential, such as prostaglandin E3, which stimulates blood flow and facilitates the repair of damaged tissue (23).

During the inflammatory response commonly seen in muscle injuries, the excessive production of reactive oxygen species contributes to muscle damage, can prolong the inflammatory phase, and delay tissue regeneration. Excess ERO further damages the structure of muscle cells, which can lead to the loss of myocytes and a decrease in muscle strength (24). A recent study has demonstrated an inverse relationship between the amount of antioxidants in the diet and sarcopenia, highlighting the potential benefits of antioxidant intake with regard to muscle mass loss (25). Antioxidant supplementation has emerged as a potential ergogenic strategy aimed at reducing oxidative stress and modulating the inflammatory response, thereby accelerating recovery from muscle injuries and improving the quality of tissue regeneration.

Curcumin, whose chemical formula is 1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadien-3,5-dione, is the main phenolic compound in turmeric root, which is used in traditional Chinese medicine to treat pain, inflammation, and various diseases (26). Dietary polyphenols are known for their ability to modulate inflammation and muscle pain without negative side effects, making them ideal for use in a sports context (27), although their effectiveness as a supplement has been limited by their low bioavailability; therefore, finding a new form of supplementation could improve their bioavailability (28), thereby enhancing the body's ability to recover from exercise-induced muscle damage (EIMD). Curcumin has been shown to have membrane-protective effects, antioxidant capacity, and anti-inflammatory action. The anti-inflammatory properties attributed to curcumin are due to its ability to inhibit nuclear factor kappa (NF-κB), which is considered a protective and muscle-regenerating agent that plays an important role in regulating the physiological mechanisms of inflammation and protein degradation (29).

Curcumin exerts anti-inflammatory effects by regulating inflammatory signaling pathways and inhibiting the production of inflammatory mediators, as shown in Figure 1.2. Curcumin binds to Toll-like receptors (TLRs) and regulates transcription factors and signaling pathways, such as NF-κB, mitogen-activated protein kinases (MAPKs), and activator protein 1 (AP-1), thereby modulating inflammatory mediators. Furthermore, it can inhibit the activation of NF-κB through the peroxisome proliferator-activated receptor (PPARγ). It also exerts anti-inflammatory effects by regulating the Janus kinase/signal transducer and activator of transcription (JAK/STAT) signaling pathway. Finally, curcumin can directly inhibit the formation of the NLRP3 inflammasome or its activation by suppressing the NF-κB pathway, which could represent one of its main mechanisms for treating inflammatory diseases (26).

Collagen is the main extracellular component of connective tissue, which gives tissues their elasticity. Collagen accounts for 25–30% of the body's total protein (30). The collagen-rich tissues of the muscular extracellular matrix play an important functional role in skeletal muscle; therefore, it is argued that the structure and function of musculoskeletal tissues—such as tendons, ligaments, and bones—depend on their collagen-rich extracellular matrix. Collagen also provides stability and protection, in addition to contributing to the structural integrity of tissues. Therefore, there is a constant

process of collagen breakdown and synthesis to perform these functions, with a turnover rate of 0.5–2% per day (31). This collagen turnover rate translates to a half-life of between two and five months (30).

Muscle soreness after exercise is the result of an inflammatory response caused by direct damage to skeletal muscle and connective tissue (32). Collagen peptide supplementation appears to improve serum markers related to recovery from exercise-induced damage (31).

Method

This undergraduate thesis employs a literature review methodology, with the aim of evaluating the effectiveness of certain nutritional supplements (ω-3, curcumin, and collagen) on exercise-induced muscle damage.

The search for related articles and publications took place between Monday, February 10, 2025, and Saturday, April 12, 2025. For the most part, the search for information was limited to two databases: PubMed and Google Scholar. The primary database used to obtain information was PubMed, while Google Scholar was used to supplement the necessary information from the other database.

With regard to PubMed, several keywords were used, including the following:

- *"Omega-3 Supplementation"*
- *"PUFA Supplementation"*
- *"Fish Oil Supplementation"*
- *"Collagen Peptide Supplementation"*
- *"Curcumin Supplementation"*
- *"Inflammation"*
- *"Exercise-induced muscle damage"*
- *"Muscle Soreness"*
- *"Muscle Damage"*

All of these terms were used as MeSH terms, in combination with Boolean operators, such as: ("*Omega-3 Supplementation*" OR "*PUFA*" OR "*Fish oil*") AND ("*Exercise-induced muscle damage*" OR "*Muscle soreness*"). In this particular case, 5,099 results were obtained after applying the filters.

To ensure a more precise search, the following filters were applied: articles written only in English or Spanish, published within the last 5 years, and conducted exclusively in humans. The same strategy was replicated on Google Scholar, using similar keywords and including only studies published in the last five years.

In order to provide valuable information for the review, a set of inclusion and exclusion criteria was outlined. The inclusion criteria were scientific articles related to the topic published in the last five years, including meta-analyses, systematic reviews, and clinical trials, as well as books and clinical guidelines. Conversely, exclusion criteria have been established to include any studies that could bias the accuracy of the information, such as animal studies, in vitro studies, or studies older than five years, with certain exceptions that carry significant weight in the field of research.

Finally, the impact factors of the various journals that published the analyzed studies were verified using Scimago Journal & Country Rank, with an SCR journal impact factor > 1.5 established as the criterion.

Results

First, Table 1 summarizes the studies that evaluate the effect of omega-3 fatty acid supplementation on DMIE.

The studies analyzed show mixed results. Except in the study by Barquilha et al. (20), all studies were conducted in young male populations involved in sports, which may introduce potential biases when extrapolating the results to other population groups.

Barquilha et al. (20) and VanDusseldorp et al. (33), through high-dose fish oil supplementation over extended periods—three grams per day for six weeks (20) and six grams per day for seven and a half weeks (33), reported significant reductions in CK and LDH levels. On the other hand, Yang et al. (34) They reported an antioxidant effect and a decrease in CK levels following ten days of krill oil supplementation and a single training session, although there were no changes in inflammatory markers.

In contrast, the studies by Visconti et al. (35) and Kyriakidou et al. (22) They administered up to 8 g/day of N-3 for approximately one month (35) and 3 g/day for four weeks (22). None of the trials showed significant differences compared with the placebo group, either in biomarkers of muscle damage or in those related to inflammation.

Overall, the duration of supplementation—whether prolonged (20,22,33) or short (34) does not appear to be a determining factor in the results, but rather the source or composition of the supplement, the dose, or the individual's susceptibility.

The effect on systemic inflammation appears uncertain, as only the study by Barquilha et al. (20) found favorable changes in inflammation markers, despite using doses similar to or higher than those used by other researchers.

Taken together, these findings suggest that the efficacy of omega-3 fatty acids does not depend solely on the duration of supplementation, but may be influenced by factors such as the quality and source of the supplement, as well as its fatty acid composition and EPA/DHA ratio, the administered dose, and the individual susceptibility of those receiving the supplement.

Table 1. Studies linking omega-3 supplementation to DMIE.

Author and year	Study Type	Sample	Speech	Results
Barquilha et al. 2023 (20)	Randomized clinical trial	16 untrained young men	• Supplementation with 3 capsules per day of omega-3 or a placebo for 6 weeks. • Assessment of the biomarkers CK, LDH, IL-6, PCR, and redox balance following strength training.	• Reduction of exercise-induced muscle damage, inflammation, and oxidative stress. • Improved redox balance following supplementation.
Kyriakidou et al. 2021 (22)	Randomized clinical trial	14 young, healthy men	• Supplementation with 3 g/day of omega-3 or a placebo for 4 weeks. • DMIE Assessment Following a Running Protocol and Analysis of CK, IL-6, TNF-α, and Perceived Muscle Pain.	• Significant reduction in muscle pain with omega-3. • Lower levels of IL-6 in the group receiving supplementation. • No significant differences were observed for CK and TNF-α.
VanDusseldorp et al. 2020 (33)	Randomized clinical trial	32 young men trained in endurance	• Random assignment to placebo, 2 g/day, 4 g/day, or 6 g/day of omega-3 for 7.5 weeks. • Assessment of performance, muscle pain, and biomarkers following eccentric exercise.	• 6 g/day optimized recovery and reduced muscle pain. • 2 g/day and 4 g/day showed no significant benefits compared with placebo.

Yang et al. 2023 (34)	Randomized clinical trial	30 young men trained in endurance	• Supplementation with 3 g/day of krill oil or a placebo, 3 days before and 3 days after eccentric exercise. • Assessment of CK, LDH, SOD, CAT, ERO, MDA, IL-2, IL-6, and TNF-α.	• Significant reduction in CK levels 24 and 48 hours after exercise. • Increased levels of SOD and CAT, and decreased levels of MDA. • No differences in IL-2, IL-6, and TNF-α compared with placebo.
Visconti et al. 2021 (35)	A randomized, double-blind, placebo-controlled clinical trial	26 young men trained in endurance	• Placebo supplementation, 6 g/day or 8 g/day of omega-3 for 33 days. • Induction of Muscle Damage Through Eccentric Exercise • CK Analysis and Perceived Muscle Pain.	• Elevated CK levels were observed in all post-exercise groups. • There were no significant differences in muscle recovery. • No dose-response relationship was observed in recovery.

Second, the evidence regarding the use of curcumin for the treatment of DMIE is summarized in Table 2.

With regard to the modulation of the inflammatory response resulting from muscle damage, only the study by Tanner et al. (27) showed a statistically significant reduction in pro-inflammatory biomarkers following administration of a combined supplement of curcumin and pomegranate extract. Since this intervention involves a supplement containing several bioactive substances, its positive effects cannot be attributed solely to curcumin.

For their part, Mallard et al. (28) and Basham et al. (36) designed independent protocols with different doses but similar durations: three grams of curcumin daily for four weeks (28) or one and a half grams of curcumin for four weeks (36), but none of the studies reported significant changes in IL-6, IL-10, or TNF-α levels, nor in the serum biomarkers of muscle damage—CRP, LDH, and CK. The effectiveness of curcumin supplementation may depend on the dose threshold, the duration of supplementation, or even interindividual factors, such as genetic or nutritional factors.

With regard to muscle perception and damage, the clinical trial by Mallard et al. (28) It reported a significantly higher mean score for perceived muscle pain in the curcumin-treated group compared with the placebo group. In turn, Hillman et al. (37) They observed a reduction in perceived pain two and three days after taking 500 mg of curcumin twice daily. On the other hand, neither Basham et al. (36) nor Tanabe et al. (38) They observed significant differences in pain perception. The inconsistency in this evidence may be due to the variability of the different protocols used to induce DMIE, ranging from resistance exercises and plyometric jumps to soccer matches and participation in a half marathon.

Differences in the doses administered (ranging from 180 mg to 3 g per day), the duration of the supplementation protocol (ranging from a single dose to four weeks), and the protocol used to induce EIMD, as well as the small sample size (between 15 and 28 participants) and the use of combined supplementation sources, are factors that add complexity to the comparison of these studies.

Table 2. Studies linking curcumin supplementation to DMIE

Author and year	Study Type	Sample	Speech	Results
Tanner et al. 2021 (27)	Feasibility Study	18 recreational runners who completed a half marathon	• Supplementation with 1 g/day of curcumin combined with pomegranate extract compared to a control group. • Administration of the supplement before and after the race. • Measurement of inflammatory proteins and inflammation-related RNA.	• Attenuation of the systemic inflammatory response in the group receiving supplementation. • No adverse effects. • Proposal to combine curcumin with pomegranate as an effective strategy for reducing DMIE.
Mallard et al. 2021 (28)	Randomized, double-blind, placebo-controlled clinical trial	28 physically active young adults	• A curcumin-containing sports drink versus a placebo during endurance exercise to exhaustion. • Measurements taken before and up to 3 days after exercise of perceived muscle pain, lactate, LDH, CRP, IL-6, IL-10, myoglobin, and TNF-α	• Lower lactate levels in the curcumin group. • Lower perceived muscle pain scores in the intervention group. • Inflammatory biomarkers showed no significant differences. • No evidence of improvement in DMIE recovery.

Basham et al., 2020 (36)	Randomized, double-blind, placebo-controlled clinical trial	19 physically active young men	• 1.5 g/day of curcumin for 28 days. Induction of damage through eccentric exercises. • Assessment of total antioxidant capacity, MDA, TNF-α, CK, and perceived muscle pain	• Reduction in perceived exercise-induced muscle damage. • The inflammatory response was not modulated.
Tanabe et al. 2024 (38)	A randomized, crossover, double-blind, placebo-controlled clinical trial	15 young college-level soccer players	• 180 mg/day of curcumin vs. placebo, starting 1 hour before the game and continuing for up to 2 days afterward. • Measurement of muscle pain, jumping ability, and biomarkers of damage and inflammation	• No significant differences in muscle pain, performance, or biomarkers were observed between the groups. • No positive effect of curcumin on DMIE was observed.
Hillman et al. 2022 (37)	Randomized, double-blind, placebo-controlled clinical trial	22 adults, 5 women, and 17 men	• 500 mg of curcumin (or a placebo) twice a day for 10 days. • Hopping protocol for generating DMIE. • Assessment of CK, erythrocyte sedimentation rate, and perceived muscle pain (before and after)	• Elevated CK levels and pain in both groups after exercise. • Less perceived pain in the group that received curcumin supplementation. • Higher CK levels in the placebo group, but not statistically significant

				• No reduction in inflammation or pain indicators.

Finally, Table 3 presents data on studies that evaluate the relationship between collagen supplementation and DMIE.

The reviewed studies suggesting a positive effect used collagen supplementation of approximately 10 to 15 grams for at least four weeks, which may alleviate DMIE and accelerate functional recovery after exercise. The clinical trial by Kuwaba et al. (32), showed significant reductions in perceived pain and fatigue immediately following the exercise protocol, with no positive effect on CK and LDH levels. Similarly, studies such as those by Bischof et al. (39) and López et al. (40) showed a decrease in biomarkers related to muscle damage (CK, LDH, CRP, and myoglobin) following a prolonged supplementation intervention, suggesting that longer protocols—ranging from six (40) and twelve weeks of supplementation (39) could be effective in mitigating muscle damage and inflammation following exercise.

On the other hand, shorter-duration protocols, such as the intervention study conducted by Prowting et al. (41), in which 15 grams of collagen were administered daily over the course of a week. The study participants did not show any improvement in pain perception, but collagen supplementation reportedly did have a positive effect on athletic performance, suggesting that the benefits regarding pain and muscle recovery may require a longer supplementation regimen.

Similarly, the study conducted by Robberchts et al. (42) The study examined the partial replacement of whey protein with collagen, with the first group receiving only 45 grams of whey protein, while the second group received a combination of 20 grams of collagen and 25 grams of whey protein. None of the groups showed significant positive differences, so the use of collagen may not be necessary as long as the individuals' protein requirements are already being met.

In terms of functional recovery, most studies conclude that participants who receive collagen peptide supplementation maintain higher performance levels compared to control groups, which could shorten the rest time between sessions and reduce the risk of injuries caused by accumulated fatigue.

The heterogeneity of the studies highlights their limitations, as the different doses used (ranging from 3 to 20 grams per day), the duration of the supplementation protocol (ranging from a single acute dose to supplementation over twelve weeks), the differences in the exercise protocols used to induce muscle damage, and the small sample sizes represent methodological limitations that must be taken into account.

Table 3. Studies linking collagen supplementation and DMIE

Author and year	Study Type	Sample	Speech	Results
Kuwaba et al. 2023 (32)	A randomized, crossover, double-blind, placebo-controlled clinical trial	Middle-aged men with no experience in sports (*n* = 20, 52.6 ± 5.8 years)	• 10 g/day of collagen peptides or a placebo for 33 days. • Single exercise protocol for Day 29. • Isometric contraction, range of motion, CK, and LDH.	• Reduced perception of muscle pain and post-exercise fatigue. • Improved strength at 48 hours. • CK and LDH showed no significant differences between groups.
Bischof et al. 2024 (39)	Randomized, double-blind, placebo-controlled clinical trial	55 sedentary or moderately active men	• 15 g/day of collagen peptides or a placebo for 12 weeks. • Three training sessions per week. • CK, LDH, myoglobin, and CRP tests before and up to 2 days after exercise.	• A significant reduction in CK, LDH, and myoglobin was observed in the group that received collagen supplementation. • Improved post-exercise muscle regenerative capacity.
Prowting et al. 2021 (41)	Randomized clinical trial	Men familiar with endurance training (*n* = 15)	• 15 g/day of collagen peptides or a placebo for 7 days. • Eccentric Jump Protocol. • Measurements of isometric	• Maintaining performance over 24 hours. • There were no changes in pain perception.

			strength, jump height, perceived pain, and collagen turnover at 24, 48, and 120 hours.	• There were no changes in the collagen turnover rate at 24 and 48 hours.
Lopez et al. 2015 (40)	Randomized, double-blind, placebo-controlled clinical trial	8 healthy, physically active men with a mean age of 29.3 years	• 3 g/day of collagen (BioCell) or a placebo for 6 weeks. • Two resistance exercises on days 43 and 46. • Assessment of CK, LDH, CRP, perceived muscle pain, and functional recovery.	• Significant reduction in CK, LDH, and CRP in the group that received collagen supplementation. • Less loss of performance in the group that received the supplement. • Better adaptation to training in the group that received supplements.
Robberechts et al. 2024 (42)	Randomized clinical trial	22 healthy young men involved in sports (24.4 ± 2.4 years)	• 20 g/day of collagen peptides + 25 g/day of whey protein versus 45 g/day of whey protein. • 3-Week Eccentric Exercise Protocol. • Measurement of isometric strength, CK, and functional	• A 10% decrease in isometric strength in both groups. • Increased CK levels in both groups. • Partially replacing whey with collagen does not improve muscle damage or

			recovery.	performance.

Discussion and Conclusions

Based on the evaluation conducted in this study, it is important to note that the field of sports supplementation is highly controversial and heavily influenced by potential conflicts of interest, making it difficult to obtain high-quality information and to establish conclusions as definitive.

First, trials that used 3–6 g/day of omega-3 for at least six weeks showed a positive effect on recovery from DMIE. In contrast, shorter interventions and those involving <3 g/day did not yield clear benefits. Further studies are needed to establish specific recommendations, but the evidence gathered suggests that a minimum amount and duration are required to observe positive effects on DMIE.

With regard to curcumin, in studies involving daily doses ranging from 180 mg to 3 g for up to four weeks, no benefit was observed for DMIE. The only study that showed a positive effect is potentially biased by conflicts of interest, in addition to its combination with another active ingredient. It would be interesting to evaluate in the future whether there are other dosages and protocols that do have positive effects.

Finally, daily administration of 10–15 g of collagen for at least four weeks improved pain perception and had a positive effect on biomarkers of muscle pain, suggesting a beneficial effect on recovery from DMIE, whereas shorter treatment regimens had no effect on pain, nor did the partial replacement of total protein levels with collagen peptides.

The evidence evaluated in this bachelor's thesis is mixed; therefore, to accurately assess the results and make recommendations, it is necessary to conduct randomized, double-blind, placebo-controlled clinical trials with a larger and more diverse sample size, varying the exercise protocols and controlling participants' dietary patterns.

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Impacts of a holistic virtual program on nutritional status, eating habits, physical activity level, and health in adults with overweight or obesity

Impactos de un programa virtual holístico sobre estado nutricional, hábitos alimentares, nivel de actividad física y salud en adultos con sobrepeso u obesidad

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ABSTRACT

Keywords:

Virtual nutritional reprogramming, virtual weight loss, online intervention for healthy living, eating and physical habits change.

A virtual holistic weight-loss program (body, mind and nutrition) was evaluated, with the aim of transforming eating habits, physical activity and improving health in 28 participants with BMI > 27.5. The intervention guided participants to moderate energy-dense foods, prefer foods with high nutritional density and moderate the glycemic load of meals. To facilitate the changes, periodic virtual reinforcements were used: videos, weekly meetings, a forum and individual contacts. In addition, behavioural and psychological support was provided: cognitive-behavioural therapy, mindfulness, stress control, reduction of the restriction-frustration-guilt cycle and continuous improvement spiral. A statistically significant increase was observed in the consumption of sweet fruits, green leafy vegetables and non-sweet fruits, alongside a decrease in cereals, starchy tubers, legumes, dairy products, processed animal-origin foods and refined oils/fats. The average weekly physical-activity time rose from 185 min to 241 min (statistically significant), surpassing the 150 min recommended by the World Health Organization. In 12 weeks, a mean reduction, statistically significant, of 5.6 kg (~6.8 % of initial weight). Current programs take twice the time to get similar results. Additionally, there was a reduction of 3.3 kg total fat and 1.5 kg visceral fat. Improvements in health and comorbidities were reported, with no negative effects. The dropout rate was 14 %, significantly lower than rates observed in similar programs. In summary, the virtual program fully achieved its objectives, emerging as a promising alternative for healthy-weight-loss.

RESUMEN

Palabras clave:

Reprogramación alimentaria virtual, adelgazamiento virtual, intervención online para vida saludable, cambio de hábitos alimentarios y actividad física.	Se evaluó un programa virtual de adelgazamiento holístico (cuerpo, mente y alimentación), con el objetivo de transformar hábitos alimentarios, actividad física y mejorar la salud en 28 voluntarios con IMC > 27,5. La intervención orientó a moderar alimentos con alta densidad calórica, preferir alimentos con alta densidad nutricional y moderar la carga glucémica de las comidas. Para facilitar los cambios se emplearon refuerzos virtuales periódicos: vídeos, encuentros semanales, foro y contactos individuales. Además, contó con apoyo conductual y psicológico: terapia cognitivo-conductual, consciencia plena (mindfulness), control del estrés, reducción del ciclo restricción-frustración-culpa y espiral de mejora continua. Se observó un aumento estadísticamente significativo en el consumo de frutas dulces, hojas verdes y frutos no dulces, junto con una disminución de cereales, tubérculos amiláceos, leguminosas, derivados lácteos, alimentos de origen animal procesados y aceites/grasas refinadas. El tiempo medio semanal de actividad física pasó de 185 min a 241 min (estadísticamente significativo), superando los 150 min recomendados por la Organización Mundial de la Salud (OMS). En 12 semanas, se constató una disminución media, estadísticamente significativa, de 5,6 kg (~6,8 % del peso inicial). Programas existentes demoran el doble del tiempo o más para conseguir el mismo resultado. Además, se tuvo reducción de 3,3 kg de grasa total y 1,5 kg de grasa visceral. Se informaron mejoras en la salud y comorbilidades, sin efectos negativos. La tasa de abandono fue del 14 %, significativamente inferior a programas similares. En síntesis, el programa virtual alcanzó íntegramente sus objetivos, revelándose como una alternativa prometedora para alcanzar un adelgazamiento saludable.

Introduction

Overweight and obesity, defined by a Body Mass Index (BMI) > 25 kg/m^2 and > 30 kg/m^2, respectively, along with their associated comorbidities, have reached pandemic proportions, with no clear signs of reversal [1].

In 2022, approximately 43% of the world's population was overweight, and 16% was obese. The World Health Organization (WHO) estimates that by 2030, nearly 1 trillion adults and 340 million children could be living with obesity [2]. In 2023, 61.4% of the Brazilian adult population was overweight, and 24.3% was obese [3].

In the United States, obese individuals incur medical expenses that are 41% higher [4]. In 2020, the overall economic impact of obesity in the Americas accounted for more than 3% of the Gross Domestic Product [5]. In Brazil, it was 1.98% in 2019, with projections of 4.66% for 2030 [5].

Comorbidities include cardiovascular disease, type 2 diabetes, certain types of cancer, hypertension, and chronic kidney disease, among others, which significantly contribute to a reduction in quality of life and life expectancy [6].

The excellent metabolic and cardiovascular health of hunter-gatherers, a result of their lifestyle, leads them to be considered ideal models for public health promotion [7].

They were nomads and maintained a varied diet consisting of fruits (both sweet and non-sweet), non-starchy tubers, cruciferous vegetables, lean animal products, mushrooms, nuts, and honey. They engaged in adequate levels of physical activity, which helped maintain their energy and metabolic balance [8].

Metabolic flexibility allows the body to switch between fats and carbohydrates as energy sources, enabling it to adapt well to seasonal and regional variations in food supply, with weight fluctuations within parameters considered healthy [8].

With an average life expectancy of less than 30 years, the leading causes of death were: infections, high infant mortality, accidents, and violence [9]. Even among people over 50, noncommunicable diseases were very rare [10]. What changed?

The causes of obesity are complex and can be grouped into the following categories: genetics, physical activity, mental health, diet, and environmental pollutants.

It is estimated that genetics could account for between 40% and 70% of the predisposition to developing obesity [2]. However, the transition from hunter-gatherer societies to modern lifestyles was too brief to allow for major genetic changes that would contribute to obesity. What happened was that the environmental changes were so drastic that genetics did not have time to adapt to the new conditions [11].

We constantly hear that one of the causes of obesity is a sedentary lifestyle. However, while hunter-gatherers engage in higher levels of physical activity (they walk a lot, move around, and forage), recent studies show that their daily energy expenditure was not significantly higher than that of the average modern population [10].

This explains why the WHO's recommendations are moderate: 150 to 300 minutes per week of moderate-intensity aerobic activity, or 75 to 150 minutes of vigorous-intensity activity, or an equivalent combination. In addition, older adults should engage in muscle-strengthening activities that involve all major muscle groups at least two days a week [12].

Even so, it is estimated that approximately 81% of adolescents (ages 11–17) and 27.5% of adults worldwide do not meet the recommended levels of physical activity [13].

The relationship between mental health and obesity is complex and bidirectional, with interdependent effects [14], including: chronic stress, anxiety, depression, emotional eating, sleep disorders, and issues related to self-image and self-esteem [15].

The transition to modern lifestyles transformed the neuropsychological processes involved in appetite, satiety, and energy regulation. The brain's reward circuit, which evolved to respond to food scarcity, is now overstimulated by highly palatable processed foods. In addition, sleep disturbances and circadian rhythm disruption—which are common in urban environments—alter key hormones such as leptin (satiety) and ghrelin (hunger) [16]. These endocrine changes are accompanied by mechanical eating behavior (eating without feeling hungry) and reduced physical activity. Taken together, the interplay of heightened reward sensitivity, reduced inhibitory control, hormonal disruption, and automated habits creates a psychological and neural environment conducive to excess calorie intake, overweight, and noncommunicable diseases.

In Brazil, approximately 60% of patients with obesity have some form of psychiatric disorder—particularly stress, depression, and binge-eating disorder [17]. Mental health is also closely linked to nutrition. Even marginal nutritional deficiencies negatively affect brain and nervous system function [18]. Obesity, for its part, promotes a state of hidden chronic inflammation, a factor recognized in the pathophysiology of depression and other neurological disorders [19].

A significant portion of the **"traditional"** diet of hunter-gatherers was replaced by the **"new"** foods of the modern diet. The mastery of fire made it possible to consume starchy foods (grains, starchy tubers, and legumes). The agricultural revolution led to an abundance of these foods, [8,20,21]. Fatty meats from domestic animals replaced lean meats from game [22]. We use milk and milk products. The Industrial Revolution led to the widespread use of refined foods (white wheat flour and white rice). It also made it possible to produce highly refined foods, such as sugars, oils and fats, starches, and distilled alcohols [23]. All of these new foods replaced a significant portion of the foods from **Origins** [24].

At the beginning of the last century, the food industry revolution led to the development of a wide range of food additives (colors, flavorings, acidulants, emulsifiers, preservatives, antioxidants, non-caloric sweeteners, thickeners, anti-caking agents, among others) [25], many of which are highly controversial in terms of their safety [26].

These additives, along with advances in food processing and the communications revolution, paved the way for the industrialization of cookies [27], bread [28,29], pasta [30], potato chips [31], refined sugar [32]. In addition, carbonated beverages appeared for the first time: 1904 [33], refined vegetable oils: 1920 [34] fast food: 1921 [35], ready-to-use industrial cake mix: 1940 [36], corn flakes: 1930 [37], hydrogenated oils (trans fats): [34], In addition, the consumption of french fries at fast-food chains became popular [31], as did pizza with the advent of quick delivery services: 1980 [38], industrialization of rice cultivation and refining: 1940 [39] and the spread of the rice-and-beans combination in Brazil: 1960 [39]. All of this comes together in a **Perfect Food Storm**.

This led to significant changes in nutrition, the most important of which were: an increase in the consumption of foods with high caloric density and low nutritional density, and an increase in the glycemic load (GL) of meals.

a) Caloric Density

One of the keys to losing weight is to increase calorie expenditure and reduce calorie intake to maintain a deficit.

Based on U.S. food composition tables. [40] The ranges of caloric density (calories per 100 g) were determined for different food groups. Figure 1 illustrates a comparison

between "Traditional" and "New" foods, with the latter having a significantly higher calorie density, which is associated with overweight and obesity [41].

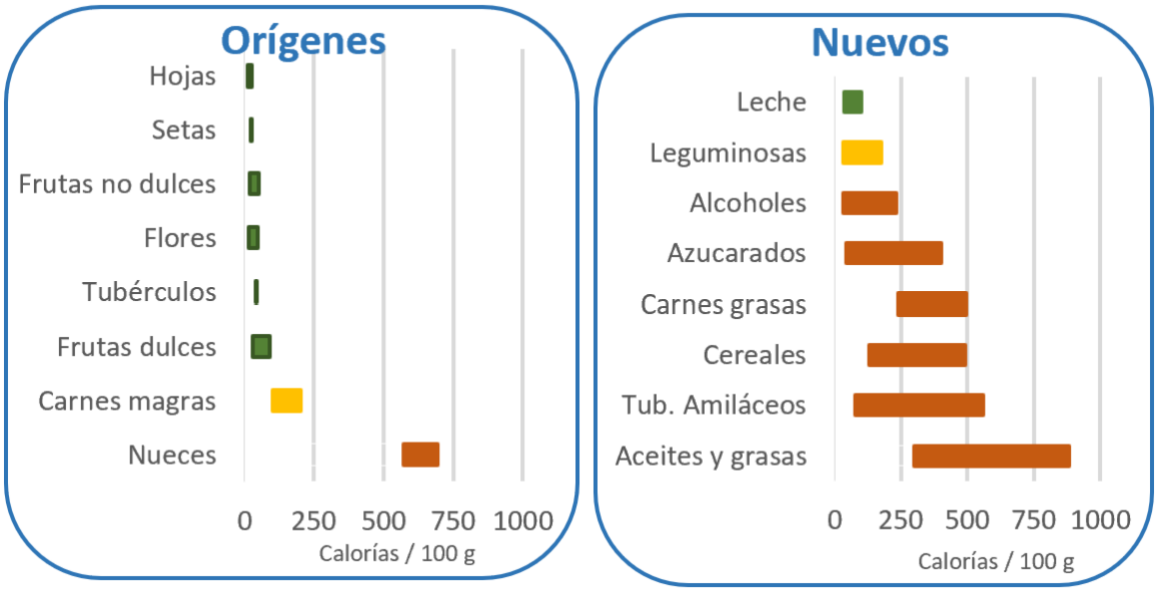

Figure 1: Caloric density
(Green: Cancel. Yellow: Media. Red: Sign Up)

b) Nutritional Density

There has recently been growing concern about ensuring an adequate intake of essential nutrients to combat the "double burden of malnutrition" (obesity caused by consuming too many calories, combined with nutritional deficiencies caused by eating nutrient-poor foods). These nutritional deficiencies, even when mild, are enough to disrupt our metabolic, physical, and mental performance, hindering efforts to lose weight and maintain a healthy weight [42]. Unfortunately, nutritional deficiencies are common in many restrictive diets [43]. One consequence of these nutritional deficiencies is low-grade (hidden) chronic inflammation, which, although it does not cause any direct symptoms, is responsible for most comorbidities in people who are overweight or obese [44].

Guiding the population in a simple and effective way toward an adequate intake of nutritious foods is a challenge due to factors such as: low nutritional/food literacy [45], information overload and misinformation [45], resistance to changing habits, socioeconomic and food access barriers, and limitations among health professionals [46].

Various initiatives have been implemented, including dietary re-education [47], dietary guidelines [48], nutrition labeling [49], nutrition claims [50] and front-of-package labeling [51], with results falling short of expectations.

A recent proposal is the concept of Nutritional Density [52]. For this paper, the following definition was chosen: "times the daily requirement for a nutrient, based on the amount of food that meets the daily requirement in terms of calories."

To operationalize this concept, the Recommended Daily Intake (RDI) values for each nutrient, as defined by the Food and Nutrition Board of the U.S. National Academies, were used. [53], in combination with data from U.S. food composition tables. [40], allowing for the calculation of the percentage of a nutrient's daily requirement present in 2,000 calories (the requirement for an average adult male). Next, the average was calculated for 12 vitamins, 8 minerals, fiber, and protein.

It was observed that foods within the same group tend to be rich or poor in the same nutrients [54]. This allowed us to estimate the representative average nutritional density for a food group, taking into account the most characteristic foods.

In Figure 2, we can see that "Original" foods have high nutritional density, while most "New" foods have low nutritional density; some of them are even "empty calories" (they provide calories but little or no other essential nutrients).

Although this assessment does not include polyphenols—since no RDI has been established for them—we know that fruits (both sweet and non-sweet), cruciferous vegetables, non-starchy tubers, mushrooms, and nuts are rich in these nutrients. The polyphenol content of modern foods, especially refined ones, is already significantly lower [55,56], which underscores the high nutritional value of Orígenes foods.

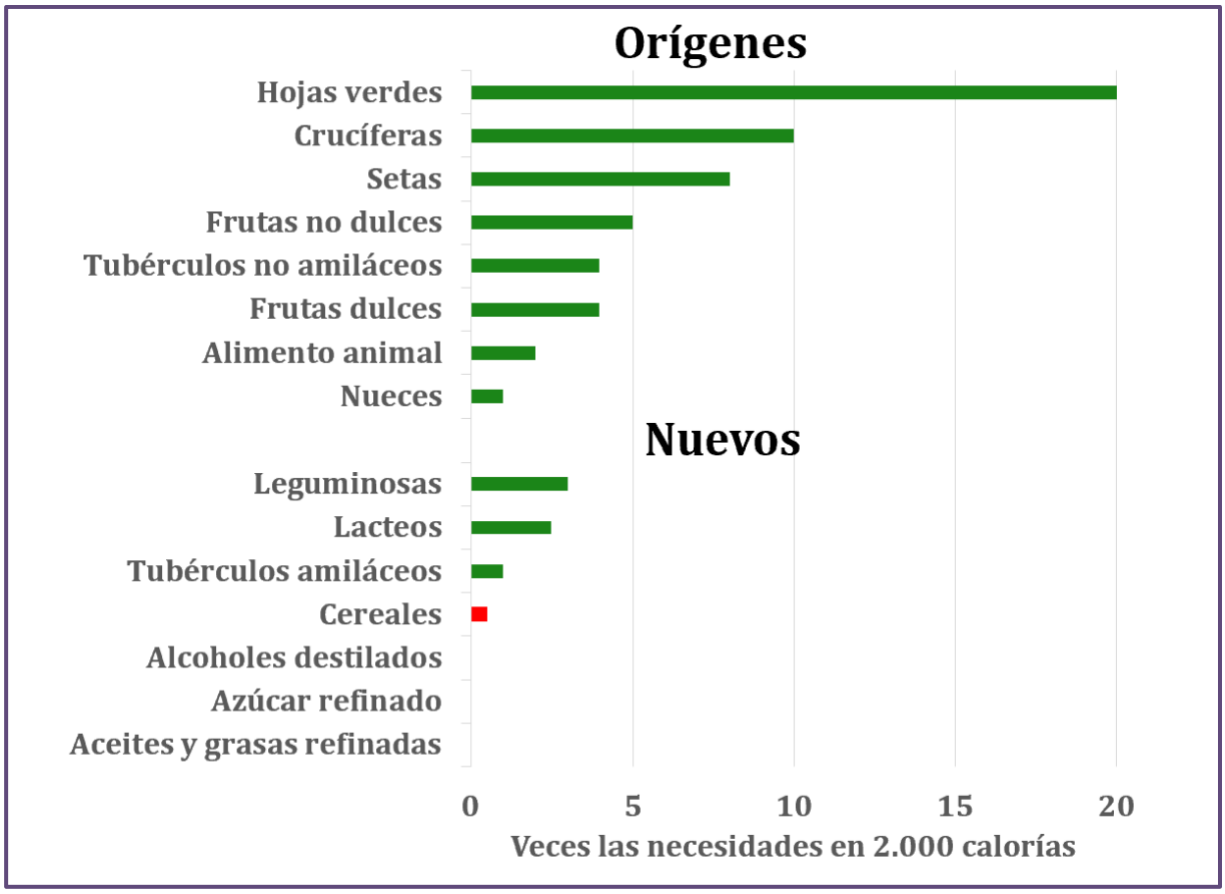

Figure 2: Average Nutritional Density by Food Group

Furthermore, by comparing Figures 1 and 2, we can see that most foods with low caloric density also have high nutritional density, establishing a synergy between the two concepts and making it easier to choose more appropriate foods [57].

It is striking to note that 45.2% of the calories in the modern Western diet come from empty calories (refined oils, fats, and sugars) and 21.9% from foods with low nutritional density (grains and starchy tubers). Fruits and vegetables account for just 4.4% of the calories. Foods of animal origin account for 25%, while legumes, nuts, and oilseeds—which have an average nutritional density—account for just 4.4% [24]. This explains the high prevalence of nutritional deficiencies.

c) Glycemic Load (GL)

It is recommended to prioritize foods with a low glycemic index (GI) [58]. However, it is the CG (GI multiplied by the amount of carbohydrates in a serving) that

determines a meal's glycemic response, which is classified as low < 10 g, moderate 11 to 19 g, and high > 20 g [59].

Frequent consumption of meals with a high glycemic load results in constant, sharp spikes in blood glucose and insulin levels, which are associated with obesity and its comorbidities [60].

Excess glucose is stored as glycogen in the muscles and liver. As glycogen stores become saturated, excess glucose is converted into fatty acids and stored in adipose tissue. Calories from fat and excess protein follow the same path. As a result, the body's metabolism is geared toward using glucose as its primary source of energy. To burn fat (both stored fat and fat from food), it is necessary to moderate the glycemic load of meals to reduce glycogen stores, which allows the metabolism to shift. [61].

Although it is difficult to estimate the ketogenic potential (CG) of the hunter-gatherers' diet, all evidence suggests that it was extremely low, fluctuating between ketogenic periods (very low) and low periods (around 10 g) [62]. A recent assessment found that the average daily carbohydrate intake in the U.S. is 133 g, which is equivalent to 44 g per meal (assuming the population eats 3 meals per day) [63], well above the diet described in *Origins*.

d) Other Changes

Heat treatment destroys vitamins and promotes adverse reactions, such as the formation of acrylamide (resulting from the interaction between starches and proteins) and nitrosamines (formed by the reaction of nitrite with proteins), both of which are recognized as carcinogens [64].

Convenience, combined with today's fast-paced lifestyle, has altered traditional eating patterns: greater reliance on fast food, frequent eating away from home, and less time spent preparing meals, all of which negatively impact the nutritional quality of the diet [64].

Genetic selection has made it possible to select plants and animals with favorable genetic traits, such as resistance to environmental variations, disease tolerance, higher productivity, and better organoleptic qualities [65]. However, varieties with lower nutritional value and higher levels of toxins and antinutrients were inadvertently selected [65].

In addition, environmental pollution worsened as a result of the introduction of chemical compounds that persist in the environment [66]. Among these, endocrine disruptors (such as bisphenol A, phthalates, pesticides, and flame retardants) stand out, as they are implicated in hormonal and metabolic dysfunction [67], antibiotics, and growth-promoting hormones used in animal feed, whose residues induce bacterial resistance and potential endocrine imbalances in consumers [64]. The role of pesticide/agrochemical use in the onset or worsening of chronic noncommunicable diseases is increasingly well documented [68]. At the same time, nanoparticles (<100 nm) originating from industrial processes were detected; their toxic effects include oxidative stress, inflammation, and possible cellular damage [69,70]. The environment was also contaminated with heavy metals, such as lead and cadmium [71], as well as complex chemical mixtures (pesticides, herbicides, PCBs, PFAS) [72]. Finally, combustion gases generate a variety of air pollutants—gases and particulate matter—that contribute significantly to the development or worsening of noncommunicable diseases [73].

Various medications can contribute to the development of obesity by increasing appetite, causing fatigue, or interfering with nutrient absorption. Notable among these drugs are those used to treat diabetes, epilepsy, and high blood pressure, as well as antipsychotics and antidepressants [74]. Treating a comorbidity can contribute to the

onset or worsening of obesity, which will make it more difficult to treat the comorbidity being addressed and may lead to the development of other comorbidities.

The dramatic decline in height following the onset of the agricultural revolution was already a warning sign. Reliance on a limited variety of foods and living in settlements led to a decrease in life expectancy, an increase in infectious diseases, and a rise in nutritional deficiencies [75].

The refining of foods during the Industrial Revolution led to an increase in nutritional deficiencies: scurvy (vitamin C), pellagra (niacin), beriberi (vitamin B_1), iron-deficiency anemia (iron), goiter (iodine), xerophthalmia (vitamin A), spina bifida (folic acid), among others [23].

Overcrowding in permanent settlements, combined with reduced immunity, contributed to the spread of infectious diseases [75]. At the same time, changes in diet led to alterations in the composition of the gut microbiota [75].

It is estimated that more than 50% of deaths from noncommunicable diseases are related to low-grade (hidden) chronic inflammation [44]. There is a vicious cycle between hidden inflammation and obesity. Silent inflammation disrupts metabolism and negatively affects the regulation of hunger and satiety, leading to an increase in adipose tissue, which, in turn, contributes to the production of elevated levels of inflammatory cytokines, thereby perpetuating the cycle of silent inflammation [76]. This inflammation is caused by: spikes in blood glucose and insulin levels [77] high consumption of trans fats [78]; a high omega-6 to omega-3 ratio [79]; additives in processed meats [80]; excessive alcohol consumption [81]; allergies [82]; gut microbiota dysbiosis [83]; lactose intolerance [84]; gluten intolerance [85]; artificial additives [86]; environmental contaminants, pesticides, heavy metals [87]; nutritional deficiencies, particularly of antioxidant and anti-inflammatory nutrients [88]; stress [89]; sedentary lifestyle [90]; low intake of soluble fiber [91]; smoking [92]; endocrine disruptors [93] and sleep disturbances [94] Various studies indicate that, to combat hidden inflammation, it is necessary to reduce exposure to the aforementioned inflammatory agents and adopt a diet rich in anti-inflammatory compounds [95].

Starting in the 20th century, there were major advances in vaccines, antibiotics, sanitation, medical care, disease diagnosis and treatment, better education, food fortification, increased purchasing power, and a reduction in smoking, all of which contributed to increased life expectancy [96]. Conversely, the rise in noncommunicable diseases due to changes in diet is causing life expectancy to begin to decline [97].

The modern Western diet causes an imbalance in the gut microbiota (dysbiosis), which is associated with metabolic problems, inflammatory diseases, mental health issues (such as anxiety and depression), and gastrointestinal disorders [98].

The intervention program focuses on managing the three most important hormonal systems involved in regulating satiety: 1) Maintain stable blood glucose and insulin levels by eating meals with a moderate glycemic load [99]. 2) Keep ghrelin levels low by choosing foods that remain in the stomach longer [100–102], where, for proteins, it is longer than for saturated fats and longer than for fiber [103]. 20 to 30 g of protein produce a feeling of fullness that lasts 3 to 6 hours. Larger amounts do not significantly increase this effect [104]. 3) Maintain an adequate intake of protein, soluble fiber, polyphenols, and omega-3 fatty acids, all of which play a crucial role in regulating appetite through the hormone GLP-1 (glucagon-like peptide) [105].

Strategies for combating obesity include: dietary education, diets, regular physical activity, medication, meal replacements, and bariatric surgery [106].

Diets include calorie, fat, or carbohydrate restriction; alternative eating patterns (Mediterranean, Paleolithic, vegetarian/vegan, ketogenic, and carnivore); intermittent fasting; and the use of meal replacements [107,108].

Governments have contributed by developing dietary guidelines [109], nutrition labeling [110], front-of-package labeling [111], nutritional claims [112] and taxes on foods considered unhealthy.

Despite the individual advantages of each strategy, the "rebound effect" remains a common problem. In addition, the effectiveness of weight loss tends to decrease with successive attempts [113].

The importance of healthcare professionals is clear [114]. However, many doctors do not feel adequately prepared [115]. In addition, clinical practice often focuses on pharmacological treatments, while lifestyle changes receive less attention [115]. The importance of psychology has recently been highlighted [116]. A holistic approach involving doctors, nutritionists, and psychologists yields better results [117].

The media has a complex relationship with obesity and noncommunicable diseases. The industry frequently advertises unhealthy products [118], Promotion of healthy foods is rare and limited to isolated initiatives by small producers or regional associations [119]. In addition, digital media often portray unrealistic body standards and lifestyles, promoting harmful eating and physical activity habits [120]. Misinformation and vague advice increase consumer confusion, leading them to make poor choices [118]. Incorrect information tends to persist in the media, prolonging the confusion [118].

Information Technology (IT) solutions can be used to develop healthy habits. In Brazil, most people own a cell phone [121] and spend an average of more than 4 hours on social media, with WhatsApp, Facebook, and Instagram being the most widely used [122]. Advances in 5G technology enable fast data transmission, leading to a better experience [123]. The Brazilian healthcare market is rapidly adopting IT [124,125]. There are already apps for tracking habits, physical activity, nutrition, heart rate, and sleep patterns. There are communities for sharing experiences and providing mutual support [126]. Virtual coaching services provide personalized professional guidance through digital platforms. Artificial intelligence is rapidly making inroads into the Brazilian healthcare sector [127].

A recent publication evaluated 8 studies that used web-based platforms and showed good results [128]. Another meta-analysis found that interventions using IT produce better results [129].

Changing habits requires considerable effort and time [130]. Barriers include: lack of motivation, an unfavorable environment, lack of knowledge, fear of failure, old habits that are difficult to break, lack of social support, unrealistic expectations, lack of time, and resistance to change [131,132]. Deep-rooted misconceptions cause confusion and are difficult to change [133].

Nutrition is a relatively new and highly complex science that requires large-scale, long-term research and significant resources, which means that areas of uncertainty still exist (for example: margarine or butter, whether or not to eat eggs, fruit for people with diabetes, etc.) [134]. Commercial and political interests, as well as inappropriate professional practices, contribute to this confusion (for example, the myth—dating back more than 70 years—about the harmful effects of saturated fats) [135].

To make matters more complicated, we have to deal with the forgetting curve (in a week, we'll remember about 20% of what we saw today) [136]. Frequent reinforcement at short intervals is more effective than spaced reinforcement in promoting sustainable changes [137].

The cost of in-person professional coaching makes it difficult for many people to attend frequent sessions aimed at changing habits [138].

Table 1 provides a summary of the holistic restructuring plan under review:

Table 1: Elements of the intervention plan

- Limit foods that are high in calories,
- Choose foods with high nutritional density
- Keep the glycemic load to about 10 g per meal; ideally, one piece of fruit
- Eat meals before you feel hungry (about every three hours).
- Start every meal with a glass of water.
- Start lunch and dinner with a hearty salad, followed by a serving of animal-based food (approx. 125 g raw, equivalent to 100–110 g cooked) accompanied by a generous portion of hot vegetables. Finish with a source of carbohydrates, ideally a piece of fruit.
- Engage in moderate and enjoyable physical activity
- A continuous process of education, persuasion, and reinforcement based on evidence, through daily videos, weekly virtual meetings, a forum, and personal contact via WhatsApp
- Use of psychological tools: developing a big-picture perspective, the spiral of continuous improvement, cognitive-behavioral therapy, mindfulness, and coping with stress and the cycle of restrictions, frustrations, and guilt.

Method

To assess the effectiveness of the proposed program, an experimental, longitudinal, descriptive study with a mixed-methods approach (qualitative and quantitative) was designed and approved by the Brazilian Ethics Committee.

Participants were selected using non-probability sampling, by sending a WhatsApp message to the researcher's circle of contacts. Eligible participants were those over 18 years of age, with a BMI > 27.5, who were comfortable using cell phones, who wished to lose weight, and who were able to attend the initial and final in-person meetings. Pregnant women, people with eating disorders (bulimia, anorexia nervosa, and binge eating disorder), and vegans were excluded.

A total of 50 participants completed the online medical history questionnaire, which asked about gender, age, height, weight, target weight, physical activity, diagnosed comorbidities (type 2 diabetes, hypertension, depression, high cholesterol, constipation, fatty liver, hypothyroidism, anemia, osteoporosis, sarcopenia), use of supplements, weight-loss medications, and regularly taken medications, food intolerances, stress levels, and general aspects of eating habits and attitudes.

Of the 28 people who signed the Informed Consent Form and began the program, four dropped out (a dropout rate of 14%). Two people were unable to participate in the final event (one had a leg in a cast and the other was on a business trip), but these are not considered withdrawals. Twenty-two people completed the program (20 women and 2 men), with an average age of 57.5 years.

Participants were added to a WhatsApp forum to share experiences and ask questions, and they registered on the support platform (www.praam.net), which provides daily videos ranging from 5 to 10 minutes in length. In addition, the platform provides a summary of the appropriate serving sizes for 10 g of CC (culinary units, weight, calories, and nutritional density) for the most common foods,

Participants were asked to complete online questionnaires on Eating Habits (developed and validated by the ELSA-Brazil project [139], which measures the frequency of food consumption) and Physical Activity (developed and validated by the ELSA-Brazil project [140], which assesses the type, frequency, duration, and intensity of activity).

Based on the responses, individual evaluations—including areas for improvement and personalized action plans—were sent (via private WhatsApp). In the most challenging cases, a personalized virtual meeting was held to exchange ideas. Participants with high levels of stress and depression were advised to seek additional professional support. To prevent demotivation, those with unrealistic goals were advised to adjust their goal to losing about 10 kg during the first three months of the program.

Participants were invited to an in-person session for fasting weight measurement (between 8:00 a.m. and 9:00 a.m.) using bioimpedance (an Omron scale, model HBF-226, which measures: weight (kg ± 100 g), total body fat (% of total weight ± 0.1%), visceral fat (% of total body fat ± 1%), and skeletal muscle mass (% of total weight ± 0.1%)). After weigh-in and breakfast, there was a brief introduction to the program.

In order to correct any preexisting nutritional deficiencies and dysbiosis that could compromise the program's effectiveness, it was suggested that a vitamin-mineral supplement, probiotic, prebiotic, and omega-3 be included during the first month.

We have asked that you post your fasting weight on Fridays—using your own scale—either on the forum or via personal WhatsApp. In return, they received feedback through the same channel, with the goal of boosting their self-esteem and identifying opportunities for improvement, in line with the concept of the spiral of continuous improvement.

The content and sequences of the daily videos were designed to persuade and gradually encourage the changes listed in Table 1.

The virtual group meetings, held every Saturday and lasting about an hour (recorded so participants could watch them later if necessary), supported the process of changing habits by answering questions and sharing experiences.

If necessary, participants were able to contact the program mentor privately (via WhatsApp) to discuss confidential matters. Similarly, the mentor reached out to participants who were underperforming in order to assess their challenges and support them through the process of change.

At the end of 12 weeks, another in-person visit was held to measure the final body composition (weight, total body fat, visceral fat, and skeletal muscle mass), and participants were asked to complete the Dietary Habits and Physical Activity questionnaires again. In addition, participants were asked to complete the "How Was My Journey?" questionnaire, which assessed their perceptions of improvements in health (overall and regarding preexisting conditions) and their level of satisfaction with the videos (number viewed, clarity, and relevance of the content), virtual meetings (participation and usefulness), the WhatsApp forum (participation and usefulness), and their willingness to recommend the program.

After the 12-week intensive period ended, participants continued in the program for another 9 months, with the difference that there were no longer daily videos and the virtual meetings became monthly, aimed at reinforcing the changes in habits they had developed.

Results

Table 2 shows the p-values for Student's t-test for paired samples and the effect size measured by Cohen's d, confirming that there was a statistically significant increase in the frequency of consumption of "Traditional" foods and a statistically significant decrease in the frequency of consumption of "New" foods. Among the Orígenes foods, there was a statistically significant increase in the consumption of sweet fruits, leafy greens, and vegetable soup. The reduction in non-sweet fruit is at the statistical threshold. In the "New" food group, a statistically significant decrease was observed for: cereals, starchy tubers, legumes, dairy products, processed animal-based foods, and refined oils and fats. These changes are in line with the goal of reducing the intake of foods with high caloric density (Figure 1) and increasing the intake of foods with high nutritional density (Figure 2).

Table 2: Changes in Eating Habits

Origenes				
	Inicio	Final	p de t student	d de Cohen´s
Frutas dulces	2,59	4,04	1,1E-03	0,83
Hojas verdes	1,52	2,38	4,3E-03	0,70
Frutos no dulces	1,63	2,13	5,3E-02	0,45
Tubérculos	0,87	0,90		
Crucíferas	0,59	0,90		
Sopa hortalizas	0,07	0,24	1,0E-02	0,62
Nueces	0,28	0,15		
Alimento animal	2,82	3,11		
	10,37	13,85	1,4E-03	0,80

Nuevos				
	Inicio	Final	p de t student	d de Cohen´s
Cereales	3,20	1,99	1,0E-02	0,62
Tubérculos amiláceos	0,92	0,57	1,6E-02	0,57
Leguminosas	1,11	0,61	3,9E-03	0,71
Leche	0,59	0,41		
Derivados de leche	1,58	1,12	1,8E-02	0,56
Animal procesado	0,71	0,33	9,1E-03	0,63
Chocolate	0,48	0,41		
Jugos con azúcar	0,22	0,04		
Jugos sin azúcar	0,16	0,09		
Bebidas con azúcar	0,71	0,53		
Bebidas sin azúcar	1,51	1,37		
Bebidas alcohólicas	0,17	0,19		
Aceites y grasas refinadas	2,97	1,95	1,8E-03	0,78
	12,74	8,49	1,30E-05	1,23

In addition, a significant change in CG was observed for each participant, with the mean decreasing from 53.9 to 23.1 g/meal ($p = 6.2 \times 10^{-8}$ and Cohen's d = 1.72).

With regard to physical activity, a statistically significant difference was observed only for the total time spent on each activity (walking / light activity / vigorous activity), which increased from 185.1 to 241.5 minutes per week (p = 0.0051 and Cohen's d = 0.67), exceeding the 150 minutes per week recommended by the WHO.

Table 3 shows the anthropometric variations

Table 3: Anthropometric Variations

	Inicio		Final			p de	d de
	Media	DP	Media	DP	Variación	t de student	Cohen´s
Peso, Kg	83,9	16,4	78,3	16,0	-5,6	6,47E-08	1,73
IMC, Kg / m^2	31,2	6,2	29,1	6,0	-2,1	1,04E-07	1,68
Gordura total, Kg	35,5	12,2	32,1	12,0	-3,3	4,02E-05	1,14
Gordura Visceral, Kg	9,7	5,3	8,1	4,6	-1,5	2,79E-04	0,96
Músculo Esquelético, Kg	20,7	3,8	20,3	5,3	-0,4	5,22E-01	0,14

Figure 3 shows the weekly changes in average weight for the half of the participants who lost weight more quickly (-7.9 kg) and the half who lost weight more slowly (-3.2 kg), in accordance with the guidelines that each participant chooses their own rate of weight loss.

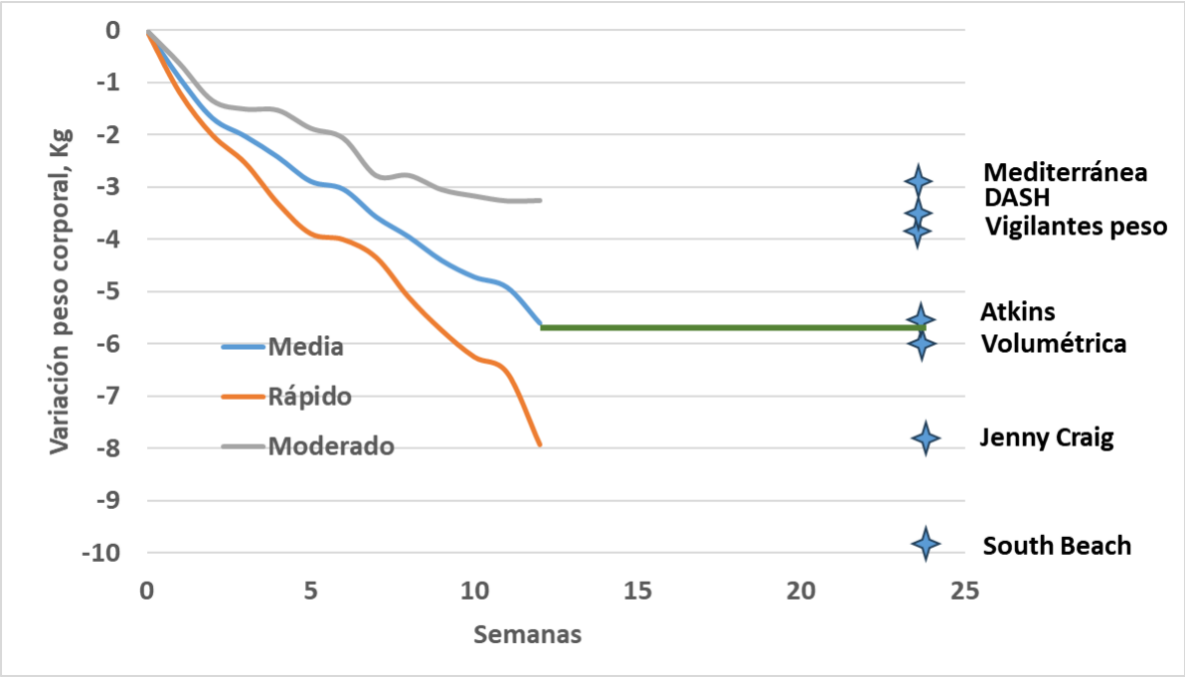

Figure 3: Weight Loss Curve

According to a recent meta-analysis that compared 14 programs over a six-month period, the ones that stood out the most were: South Beach, losing 9.9 kg; Jenny Craig, 7.8 kg; Volumétrica, 6 kg; and Atkins, 5.5 kg. [141]. With an average weight loss of 5.6 kg achieved in half the time (3 months), this program ranks among the best in the world.

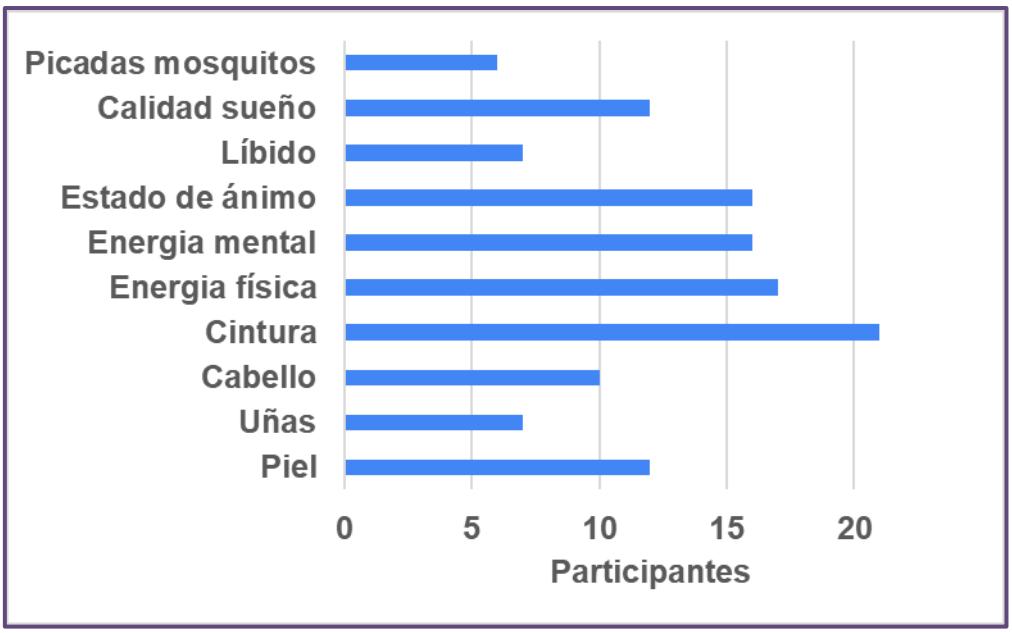

Figure 4: Perceived improvements in health in general

Figure 4 shows the number of participants who reported improvements in their overall health. No one mentioned any damage. Figure 5 shows the number of participants who reported improvements in their preexisting health conditions. Only one case reported worsening constipation, with suspected causes unrelated to the program. Several participants reported improvements in self-esteem and immunity, as well as a

reduction in feelings of guilt. During the first and second weeks, some participants reported mild headaches, which were attributed to a blood glucose level well below the recommended range. After the treatment, the symptoms disappeared.

There was a wide range in the number of videos viewed. 90% found the videos clear and relevant. Sixty percent considered participation in the weekly meetings to be "very useful," and nearly 50 percent felt that the Forum helped with the process. Everyone said they would recommend the program.

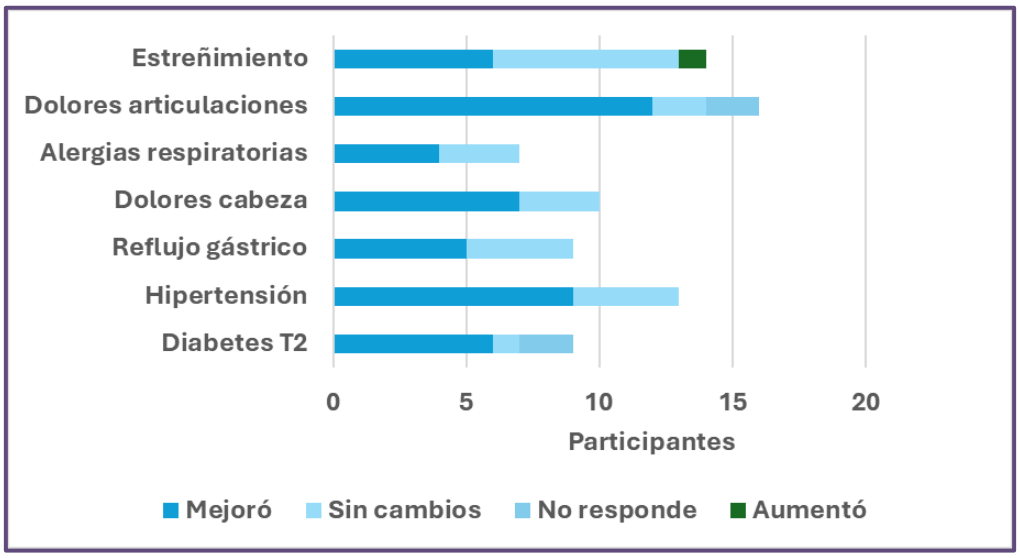

Figure 5: Perceived improvements in preexisting health conditions

Discussion and Conclusions

Changes in eating habits and physical activity confirm a shift toward a more mindful and intuitive approach, which is key to losing weight quickly and healthily. The virtual tools (initial assessment, support platform, videos, modules, forum, weekly meetings, WhatsApp conversations) and the use of psychological approaches (defining the big picture, the spiral of continuous improvement, CBT, mindfulness, and combating stress and the cycle of restrictions-frustrations-guilt) worked in holistic synergy to help participants achieve their goals.

Moderate Caloric Density

Counting calories versus moderating calorie density is a recent debate [142,143].

- Counting calories provides an accurate picture of energy balance, which is useful for those seeking detailed control, but it requires discipline and can lead to stress or obsession, in addition to not taking into account factors such as satiety and hormonal responses.
- Choosing foods with low calorie density allows you to eat larger portions, increases feelings of fullness, and promotes more intuitive eating, although it can lead to monotony.

Table 2 confirms that the strategy of moderating caloric density, as supported by Figure 1, helped reduce calorie intake, as one might expect.

Choose Nutritional Density

Table 2 also confirms the increase in consumption of foods with higher nutritional density, as shown in Figure 2.

Since several participants reported difficulty estimating portion sizes in the dietary habits questionnaire, it was not possible to quantify the variation in calorie and essential nutrient intake.

Moderate CG

After decades of debate over the benefits of reducing fat versus limiting carbohydrates, current evidence suggests that, in the long term (12 to 24 months), there are no significant differences. In the short term (6 to 12 months), moderate-carbohydrate diets appear to be more effective. The most important thing is to maintain a calorie deficit and stick to the program, regardless of the type of dietary restriction [144].

The program evaluated adopted a hybrid approach: prioritizing low-calorie-density foods (which includes reducing fats and other sources of calories) and limiting total fat intake to about 10 g. Changes in dietary habits (Table 2) and anthropometric results (Table 3) confirm the effectiveness of this approach.

Participants had no difficulty adopting this hybrid approach, in contrast to what has been reported in the literature, which indicates that extremely low-carbohydrate diets (ketogenic and carnivore) are difficult to follow and pose health risks [145].

This program was highly effective in alleviating the symptoms of most participants with type 2 diabetes, as shown in Figure 5, a finding that is widely supported in the literature [146].

It is important to note that there is significant variation in the glycemic response from one person to another and from one meal to another in the same individual, even for the same glycemic index (GI). People with higher levels of insulin resistance show more pronounced responses [147]. The state of the gut microbiome alters the response [147]. In people with a morning chronotype, the response to the same CG is greater at night than in the morning [148]. The food matrix (fiber, fat, protein) [149] and the order in which macronutrients are consumed also has an influence [150].

Moderate physical activity and enjoyable

The metabolic and psychological benefits of physical activity are numerous [151].

However, exercise reaches its full potential when combined with nutritional, behavioral, and healthy lifestyle interventions [151].

The program's recommendations to engage in moderate and enjoyable physical activity achieved their goal, reducing sedentary behavior and increasing the number of participants who engaged in at least 150 minutes of physical activity per week, as recommended by the World Health Organization [12].

Anthropometric changes: Weight

As shown in Figure 3, the program's performance ranks it among the best programs worldwide

Anthropometric changes: Visceral fat

The program promoted lifestyle changes for which there is evidence of their benefits in reducing visceral fat, such as: physical activity [152,153]. a low-calorie diet [154,155], adequate protein intake [156,157], low glycemic load [158] and an anti-inflammatory diet [158], which explains why virtually all participants reduced their visceral fat, by an average of 1.5 kg

Anthropometric changes: Skeletal Muscles

Bioimpedance results show an average increase of 1% in the percentage of skeletal muscle. However, when viewed in context, along with the total weight loss, we find that there was a non-significant average reduction of 0.4 kg, as shown in Table 3. It is important to note that when switching from a high-carbohydrate diet to one with moderate carbohydrate content, a reduction in muscle and liver glycogen (and bound water) is to be expected. Since the bioimpedance scale does not distinguish between muscle mass and glycogen, it is not possible to draw a reliable conclusion from the measurements.

Improvements Beyond Weight

Several authors point out that rapid weight loss (> 5 to 10% in less than six months) is associated with substantial health risks [159,160], including:

- Nutritional: pale skin, weakness, fatigue, hair loss, unusual cravings, constipation, depression, numbness or tingling in the joints, difficulty concentrating, among others (93),
- Psychological: irritability, fatigue, hunger, depression, anxiety, compulsive eating, and obsession with food [159],
- Physical: headaches, dizziness, constipation, menstrual irregularities, hair loss, and loss of muscle mass [161],
- Sleep: poor quality [162].

Participants lost an average of 6.8% of their body weight in just 3 months, with none of the associated risks observed. On the contrary, as shown in Figures 4 and 5, significant perceived improvements were observed in both overall health and preexisting health problems.

Holistic Approach

Traditional diets and weight-loss programs focus primarily on dietary education and physical activity. The mental aspect is often overlooked. This study helps provide evidence regarding the importance of incorporating psychological tools, such as: defining a "big picture" [163,164]; a spiral of continuous improvement [163,165]; mindfulness [166]; cognitive-behavioral therapy [167]; stress management [168]; breaking the cycle of restrictions – frustrations – guilt [169] and reducing the forgetting curve [136].

Customization

The value of adopting a personalized approach, as opposed to a "one-size-fits-all" model, was demonstrated [170]. Weekly meetings, the Forum, and one-on-one

interactions would help identify individual characteristics and needs, allowing for personalized approaches to achieve better results—such as lacto-ovo-vegetarianism, lipedema, congenital cognitive impairments, and self-sabotage patterns, among others.

Dropout Rate

The dropout rate for this study was 14%, a notable result when compared to systematic reviews that report rates ranging from 20% to 80% [171–173].

Several participants expressed at various times their intention to drop out of the program, due to skepticism, feelings of being unique ("I'm different"), limiting beliefs, a perception of stagnation (I stopped losing weight), a slow metabolism, misinterpretation of the scale, lack of time, stress, depression, feelings of guilt, cognitive distortions, travel, illness, accidents, and work-related exhaustion ("burnout").

The support tools and holistic approach were essential for identifying and addressing these situations early on, while maintaining a high level of motivation, commitment, and performance, along with a low dropout rate.

Cost-Effectiveness

The Incremental Cost-Effectiveness Ratio (ICER) is used to compare two intervention programs; it is defined as the difference in costs divided by the difference in the effect achieved by both programs [174,175]. Digital weight-loss interventions show evidence of being cost-effective compared to in-person care [174,175].

Without attempting to provide a detailed analysis, the findings of this study show that it is highly effective for weight loss and improving health. At the same time, the cost estimate was lower than initially projected. This result suggests that this program has the potential to establish itself as a promising alternative in the field of healthy weight loss services, while also being cost-effective.

Conclusions

The results of this study confirm that the program under evaluation achieved its overall goal of promoting healthy weight loss.

The rapid and significant changes in dietary habits and physical activity, the evident improvements in health, the high effectiveness compared to other programs, the ease of customization, the low dropout rate, and the good cost-effectiveness ratio show that the program has the characteristics to rank among the most effective and innovative globally, benefiting both those who wish to lose weight and the professionals who implement it.

Among the limitations were: 1) bioimpedance analysis proved difficult to use for assessing changes in muscle mass; 2) the dietary habits questionnaire did not provide reliable data for assessing changes in calorie and essential nutrient intake; and 3) the results regarding health and well-being were based on participants' perceptions, which poses a risk of subjective bias. These are areas worth exploring in the future.

Given the chronic nature of obesity and the challenges associated with weight maintenance, it is worthwhile to conduct follow-up longitudinal studies with participants to assess the long-term sustainability of the results achieved.

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Conflict of interest:

The author states that he is interested in launching a startup based on the results presented in this study. This initiative did not influence the study design, data collection, or data analysis; the research was conducted independently, and all procedures, methodological decisions, and results accurately reflect the original data.

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Body composition and dietary intake in male amateur rugby players, juvenile category M15 and M16 of Tigres Rugby Club, San Lorenzo

Composición corporal e ingesta alimentaria en jugadores masculinos de rugby amateur, categoría juvenil M15 y M16 de Tigres Rugby Club, San Lorenzo

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ABSTRACT

The study aimed to analyze the relationship between body composition and dietary intake in male youth amateur rugby players from Tigres Rugby Club (San Lorenzo). A cross-sectional, observational, descriptive, and correlational study was conducted. Anthropometric measurements were assessed using the ISAK protocol, and energy and macronutrient intake were measured using 24-hour dietary recalls in 53 players from the M15 and M16 categories (backs and forwards). The results indicated that the majority of participants had adequate levels of body fat (64%) and muscle mass (83%), although 36% showed excess fat and 17% muscle deficit, with a higher prevalence among forwards. Regarding energy intake, 62% reached adequate levels, with a tendency towards excess calories in some backs and a deficit in certain forwards. The macronutrient distribution revealed insufficient carbohydrate intake (73%) and excesses in fats (96%) and proteins (36%). Furthermore, a dietary pattern was observed characterized by high consumption of ultra-processed foods and low intake of fruits and vegetables. No statistically significant associations were found between body composition and intake; however, trends suggest that excess adipose tissue and muscle mass development in players are more related to diet quality and macronutrient distribution than to total caloric intake, along with factors specific to adolescence, such as growth and maturation.
In conclusion, although overall body composition is adequate, poor dietary quality is evident, requiring nutritional interventions tailored to youth rugby.

Palabras clave:
masa adiposa, masa muscular, calorías, macronutrientes, recordatorio de 24 horas.

RESUMEN

El estudio tuvo como objetivo analizar la relación entre composición corporal e ingesta alimentaria en jugadores masculinos juveniles de rugby amateur de Tigres Rugby Club (San Lorenzo). Se realizó un estudio observacional, descriptivo y correlacional de corte transversal. Se evaluaron medidas antropométricas mediante protocolo ISAK y la

ingesta energética y de macronutrientes mediante recordatorios de 24 horas en 53 jugadores de categorías M15 y M16 (backs y forwards).
Los resultados indicaron que la mayoría presentó valores adecuados de masa adiposa (64%) y masa muscular (83%), aunque un 36% mostró exceso de adiposidad y un 17% déficit muscular, con mayor prevalencia en los forwards. En cuanto a la ingesta energética, el 62% alcanzó valores adecuados, registrándose tendencia de exceso calórico en algunos backs y de déficit en ciertos forwards. La distribución de macronutrientes evidenció ingesta insuficiente de carbohidratos (73%) y excesos en grasas (96%) y proteínas (36%). Además, se observó un patrón alimentario con alto consumo habitual de ultraprocesados y baja ingesta de frutas y verduras. No se encontraron asociaciones estadísticamente significativas entre composición corporal e ingesta; sin embargo, las tendencias sugieren que el exceso de masa adiposa y el desarrollo de masa muscular en los jugadores se relacionan más con la calidad de la alimentación y la distribución de macronutrientes que con el aporte calórico total, junto con factores propios de la adolescencia, como crecimiento y maduración. En conclusión, aunque la composición corporal general es adecuada, se evidencia una calidad alimentaria deficiente que requiere intervenciones nutricionales orientadas al rugby juvenil.

Introduction

Rugby is a contact sport that demands high levels of strength, speed, and endurance—qualities that depend largely on a player's body composition. In youth categories, these requirements are complicated by the unique context of adolescence, a stage of life characterized by significant changes in body composition, such as an increase in muscle mass and a redistribution of body fat. These processes, which are influenced by hormonal, genetic, environmental, and nutritional factors, have a direct impact on athletic performance, injury prevention, and the player's overall physical development (1).

Muscle mass is a key factor in rugby players' performance, as it is directly linked to strength, power, and the ability to absorb the impacts typical of the sport (2).

On the other hand, body fat—although necessary in certain proportions for the body's proper metabolic and hormonal functioning—must be maintained at optimal levels to avoid adverse effects on speed, agility, and athletic performance. The balance between these two components is particularly important during adolescence, when the body is in the midst of development and energy and nutritional needs increase significantly (3).

These players' dietary intake must be tailored to the demands of training and competition, ensuring an adequate supply of energy and nutrients to meet metabolic needs and promote recovery. However, in many cases, this intake may be inadequate, which negatively affects both body composition and performance in young people (4).

According to the United Nations Children's Fund (UNICEF), most adolescents do not consume the foods that would provide them with the foundation for a long, healthy, and productive adult life. About 21% of adolescents in school eat vegetables less than once a day; 34% eat fruit less than once a day; 42% drink sugary beverages daily; 46% eat fast food at least once a week; and, in general, they skip breakfast. There are external influences that have a significant impact on the food choices made by adolescents, including peer pressure, the desire to fit in with their peers, and the marketing and widespread availability of fast food and industrially produced beverages, especially in schools and their surrounding areas (5).

Adolescents are in a vulnerable stage of life and are sensitive to stimuli related to changes in diet; this is particularly true for adolescents who participate in sports, as it is directly linked to changes in body weight or the use of sports supplements aimed at improving their performance (6).

Athletic performance in rugby is influenced by many factors, with body composition and nutrition playing a decisive role. The proper distribution of body fat and muscle mass is key to players' athletic performance, as it directly affects strength, speed, and endurance. In addition, caloric intake and a balanced consumption of macronutrients play a key role in optimizing performance and recovery, as well as in preventing fatigue and injuries (1).

Among amateur youth rugby players, there is a preference for fast food, sugary drinks, and foods high in saturated fat, as well as low consumption of fruits and vegetables; there is also an inability to meet their necessary energy requirements. This can affect body composition, compromising both athletic performance and overall physical development. However, the scientific literature provides little evidence regarding the relationship between dietary intake and body composition in this age group (7).

In the context of amateur rugby in the province of Salta, where assessments of players' body composition—specifically fat mass and muscle mass—as well as nutritional

planning by a professional may be limited, it is common to find imbalances (excesses or deficiencies) in one or both of these variables, which compromises both the players' performance on the field and their overall health.

Therefore, this study aims to analyze the body composition of male youth amateur rugby players in the U15 and U16 divisions of the "Tigres Rugby Club," with a special focus on body fat and muscle mass and their relationship to dietary intake.

Method

Body Composition

To assess body composition, anthropometric measurements were taken according to the restricted profile recommended by ISAK 2019 (8).

After obtaining institutional authorization from the club, as well as informed consent from the guardians and assent from the players, the evaluation of the adolescents was coordinated with the physical trainer for each division.

The participants were evaluated in the gym's examination room at that facility, wearing as little clothing as possible to facilitate the identification of anatomical landmarks. All measurements were taken with the subject in a standardized anthropometric position on the right side of the body.

Basic Measurements

Weight

Instrument: Digital/electronic scale. Accuracy: 100 to 50 g. Cormillot.

Method: The subject, wearing as little clothing as possible, stood in the center of the scale with his weight evenly distributed between both feet, allowing the measurement to be taken.

Size

Instrument: Self-adhesive height chart with millimeter markings. Accuracy of 0.1 cm. Argentine Gauges.

Method: The subject stood with his back to the height rod in an anthropometric position, barefoot, with his feet firmly planted on the floor, his heels touching the wall, and his head in the Frankfort plane. In this way, the distance between the vertex and the soles of the feet was measured.

Skin folds

Instrument: Plastic pleat gauge. 50 mm range and 0.2 mm accuracy. Argentine Gauges.

Method: To measure all the skinfolds, the corresponding anatomical point for each area—which had been marked beforehand—was used as a reference. To do this, the crease between the thumb and index finger of the left hand was used. With his right hand, he picked up the device and placed it 1 cm below that crease; after two seconds, he took the reading.

Perimeters

Instrument: Flexible steel anthropometric tape. Accuracy of 0.1 cm. Argentine Gauges.

Method: Once the perimeter to be measured had been encircled, the tape measure was held with enough tension to keep it in this position against the body and take the reading, directly in line with the zero mark to avoid errors caused by tilting.

Diameters

Instrument: Plastic caliper. Accuracy of 0.1 cm. Argentine Gauges.

Method: The first arm of the caliper was placed at the anthropometric point and the second arm at the other point on the short bones, and the corresponding measurement was taken.

Body Fat

To calculate body fat mass (BFM), the sum of 6 skinfold thicknesses (SP6) in mm and the Z-score for body fat were used to plug both values into Kerr's (1991) mathematical formula—an equation used in both scientific studies and the ISAK 2019 software—to estimate BFM in kilograms.

Muscle Mass

To calculate muscle mass (MM), the following variables were considered: corrected relaxed arm circumference, corrected mid-thigh circumference, and corrected calf circumference; in addition to the subject's height in meters, age, sex, and race. This allowed us to express these values using Lee's (2000) mathematical formula—an equation used in both scientific studies and the ISAK 2019 software—and to estimate the dry matter (kg).

An average was calculated for the anthropometric profile of fat mass and muscle mass in kilograms for the youth URBAREF players, broken down by playing position (forwards-backs) and division (M15-M16).

The obtained values were then analyzed in relation to the formulas for estimating body fat and muscle mass in the players, calculating an average of both by playing position (forwards-backs) and division (M15-M16), and subsequently compared with the average standards developed in-house based on the URBAREF youth guidelines.

Food Intake

A semistructured dietary survey was administered using the R24 questionnaire; to validate the questionnaire, a pilot study was conducted among adolescents who engage in regular physical activity and were not part of the sample. Once the necessary corrections were made, three R24 (9) codes were applied to all players who participated in the study: two for weekdays and one for weekends.

In this way, the daily amount of food consumed was estimated, using as a reference the household measurements expressed in grams proposed by Lic. Lucía Batrouni (2016) and the Photographic Atlas of Foods and Food Preparations by Agustina Lotufo Haddad, et al. (2022) (10,11).

To convert the data into calorie and macronutrient values, we used the food composition tables from the Food Analysis and Registration System (SARA; 2022) and the Institute of Nutrition of Central America and Panama (INCAP; 2012); for foods not listed in these tables, we used the corresponding nutritional labeling.

Next, an average of the caloric intake and macronutrient intake of the participants over the three days analyzed was calculated. Tables were created based on playing

position (forwards-backs) and age group (M15-M16) to ultimately compare these values with the required amount of calories and macronutrients and determine the percentage of adequacy.

The IOM (2002) formula was used to establish the estimated reference energy requirement, as it is one of the most up-to-date formulas and takes the adolescent population into account, allowing for the addition of a caloric factor for growth.

To establish the reference macronutrient requirements, the standards cited in the theoretical framework by Marcia Onzari, B.A., in her book *Fundamentals of Sports Nutrition; 2021* (12) were used.

Finally, to analyze the frequency of habitual consumption of the main food groups reported based on the three R24s, they were represented in a stacked bar chart according to the number of days on which they were consumed by the players, making it possible to identify those included in a single R24, in two R24s, or in all three R24s evaluated.

Results

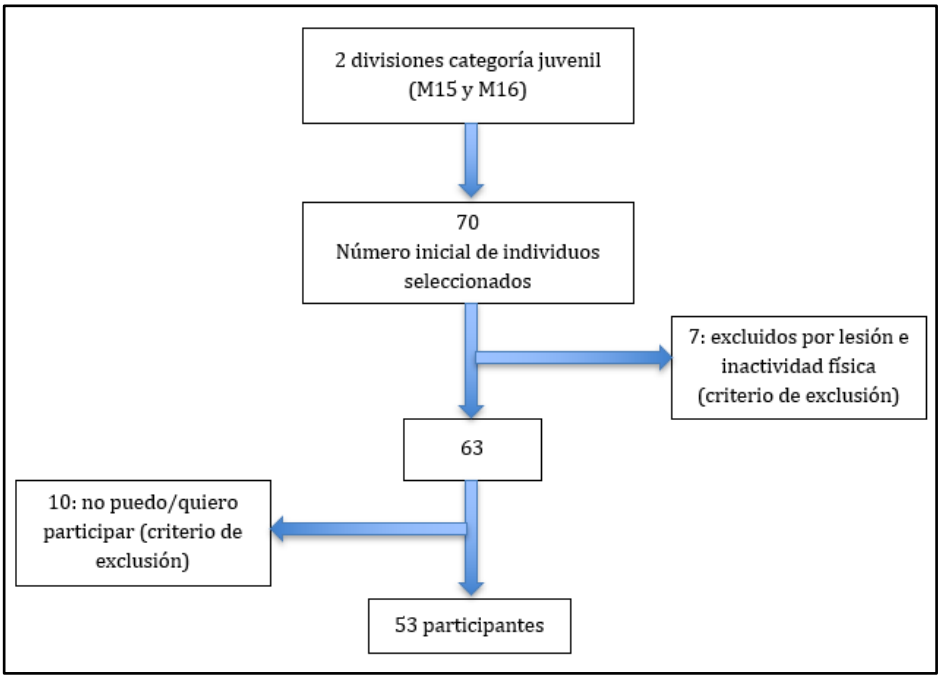

Figure 1. Flowchart for Participant Selection.

Table 1. Body Composition Statistics for Fat Mass and Muscle Mass by Division and Playing Position Among Male Youth Players of the "Tigres Rugby Club," San Lorenzo 2025.

Variables	M15 (n=26)						M16 (n=27)					
	Backs (n=14)			**Forwards (n=12)**			**Backs (n=11)**			**Forwards (n=16)**		
	M	**Min**	**Max**	**M**	**Min**	**Max**	**M**	**Min**	**Max**	**M**	**Min**	**Max**
Kg MA	14,83	12,39	21,31	21,90	14,44	37,20	18,20	13,56	21,90	24,04	14,14	38,55
Kg MM	25,56	21,38	30,60	27,75	24,59	33,40	30,47	26,60	34,77	31,93	26,45	38,30

Shapiro-Wilk: MA W=0,86; p<0,0001 (n=53). MM W=0,90; p=0,66 (n53).

Table 2. Assessment of Body Fat Mass by Position and Playing Role Among Male Youth Players of the "Tigres Rugby Club," San Lorenzo 2025.

Valoración MA	M15 (n=26)				M16 (n=27)				Total	
	Backs		**Forwards**		**Backs**		**Forwards**			
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Adecuado	10	19	9	17	6	11	9	17	**34**	**64**
Exceso	4	8	3	6	5	9	7	13	**19**	**36**
Total	14	27	12	23	11	20	16	30	**53**	**100**

Table 3. Assessment of Muscle Mass by Position and Playing Role Among Male Youth Players at "Tigres Rugby Club," San Lorenzo 2025.

Valoración MM	M15 (n=26)				M16 (n=27)				Total	
	Backs		**Forwards**		**Backs**		**Forwards**			
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Adecuado	13	24	11	21	11	21	9	17	**44**	**83**
Déficit	1	2	1	2	0	-	7	13	**9**	**17**
Total	14	26	12	23	11	21	16	30	**53**	**100**

Table 4. Caloric and Macronutrient Intake Statistics by Position and Playing Position for Male Youth Players of the "Tigres Rugby Club," San Lorenzo 2025.

Variables	M15 (n=26)						M16 (n=27)					
	Backs (n=14)			Forwards (n=12)			Backs (n=11)			Forwards (n=16)		
	M	Min	Max	M	Min	Max	M	Min	Max	M	Min	Max
Cal kcal/d	2974	2354	4370	3117	2329	3756	3217	3049	3795	3277	1861	5239
HC g/kg/d	5,48	4,26	8,69	4,51	3,41	5,37	4,70	3,54	6,40	4,07	1,37	4,88
Prot g/kg/d	2,28	1,70	2,84	1,92	1,40	2,76	1,92	1,63	2,76	1,67	1,35	2,82
Grs g/kg/d	2,49	1,86	2,96	2,10	1,57	2,79	2,06	1,89	3,01	2,16	1,10	3,17

Shapiro-Wilk: Cal W=0,93; p=0,01. HC W=0,94; p=0,05. Prot W=0,90; p<0,0001. Grs W=0,98; p=0,78.

Table 5. Assessment of Caloric Intake by Position and Playing Role Among Male Youth Players at "Tigres Rugby Club," San Lorenzo 2025.

Ingesta Calórica	M15 (n=26)				M16 (n=27)				Total	
	Backs		Forwards		Backs		Forwards			
	n	%	n	%	n	%	n	%	n	%
Insuficiente	0	0	2	4	1	2	5	9	**8**	**15**
Adecuada	7	13	9	17	7	13	10	19	**33**	**62**
Exceso	7	13	1	2	3	6	1	2	**12**	**23**
Total	14	26	12	23	11	21	16	30	**53**	**100**

Table 6. Assessment of Carbohydrate Intake by Division and Playing Position Among Male Youth Players at "Tigres Rugby Club," San Lorenzo 2025.

Ingesta HC	M15 (n=26)				M16 (n=27)				Total	
	Backs		Forwards		Backs		Forwards			
	n	%	n	%	n	%	n	%	n	%
Insuficiente	6	11	10	19	7	13	16	30	**39**	**73**
Adecuado	7	13	2	4	4	8	0	0	**13**	**25**
Exceso	1	2	0	0	0	0	0	0	**1**	**2**
Total	14	26	12	23	11	21	16	30	**53**	**100**

Table 7. Assessment of Protein Intake by Position and Playing Role Among Male Youth Players at "Tigres Rugby Club," San Lorenzo 2025.

Ingesta Prot	M15 (n=26)				M16 (n=27)				Total	
	Backs		Forwards		Backs		Forwards			
	n	%	n	%	n	%	n	%	n	%
Adecuado	4	7,5	9	17	7	13	14	26	**34**	**63,5**
Exceso	10	19	3	6	4	7,5	2	4	**19**	**36,5**
Total	14	26,5	12	23	11	20,5	16	30	**53**	**100**

Table 8. Assessment of Fat Intake by Position and Playing Role Among Male Youth Players at "Tigres Rugby Club," San Lorenzo 2025.

Ingesta Grs	M15 (n=26)				M16 (n=27)				Total	
	Backs		Forwards		Backs		Forwards			
	n	%	n	%	n	%	n	%	n	%
Adecuado	0	0	0	0	0	0	2	4	**2**	**4**
Exceso	14	26	12	23	11	21	14	26	**51**	**96**
Total	14	26	12	23	11	21	16	30	**53**	**100**

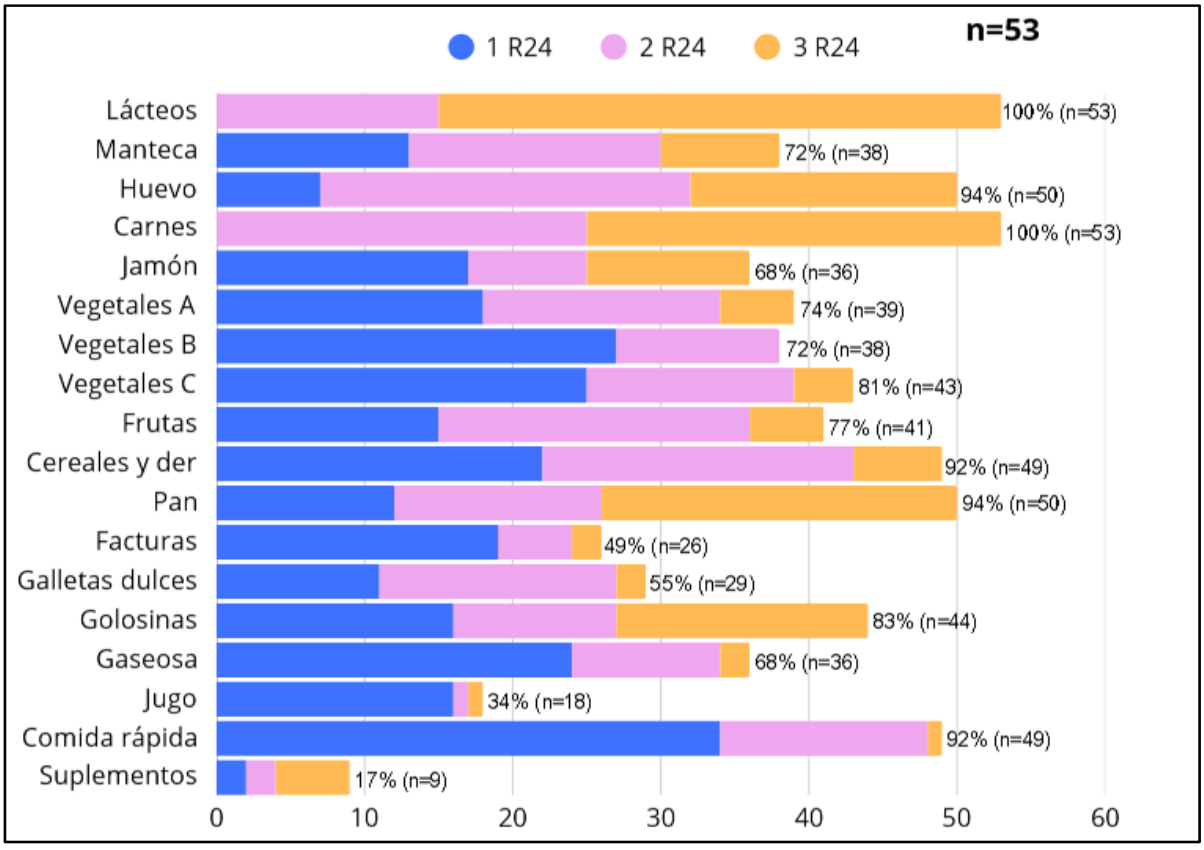

Figure 2. Typical food consumption identified in the R24s of male youth players from "Tigres Rugby Club," San Lorenzo 2025.

Table 9. Relationship Between Body Fat and Caloric Intake Among the Backs of the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta calórica	Masa Adiposa		TOTAL	p=0,09 (*)
	Adecuado	Exceso		
Adecuado	7	7	14	
Inadecuado	9	2	11	
TOTAL	16	9	25	

*Test de Fisher

Table 10. Relationship Between Body Fat and Caloric Intake Among the Forwards of the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta calórica	Masa Adiposa		TOTAL	p=0,06 (*)
	Adecuado	Exceso		
Adecuado	10	9	19	
Inadecuado	8	1	9	
TOTAL	18	10	28	

*Test de Fisher

Table 11. Relationship between Body Fat Mass and Intake in Grs Among the Backs of the "Tigres Rugby Club" M15 and M16 Teams, San Lorenzo 2025.

Ingesta de Grs	Masa Adiposa		TOTAL	p=0,16 (*)
	Adecuado	Exceso		
Adecuado	0	0	0	
Inadecuado	16	9	25	
TOTAL	16	9	25	

*Test de Fisher

Table 12. Relationship Between Body Fat and Grs Intake Among the Forwards of the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta de Grs	Masa Adiposa		TOTAL	p=0,66 (*)
	Adecuado	Exceso		
Adecuado	1	1	2	
Inadecuado	17	9	26	
TOTAL	18	10	28	

*Test de Fisher

Table 13. Relationship Between Muscle Mass and Protein Intake Among the Backs of the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta de Prot	Masa Muscular		TOTAL	p=0,36 (*)
	Adecuado	Déficit		
Adecuado	11	0	11	
Inadecuado	13	1	14	
TOTAL	24	1	25	

*Test de Fisher

Table 14. Relationship Between Muscle Mass and Protein Intake Among Forwards on the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta de Prot	Masa Muscular		TOTAL	p=0,63 (*)
	Adecuado	Déficit		
Adecuado	16	7	23	
Inadecuado	4	1	5	
TOTAL	20	8	28	

*Test de Fisher

Table 15. Relationship Between Muscle Mass and Carbohydrate Intake Among the Backs of the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta de HC	Masa Muscular		TOTAL	p=0,24 (*)
	Adecuado	Déficit		
Adecuado	10	1	11	
Inadecuado	14	0	14	
TOTAL	24	1	25	

*Test de Fisher

Table 16. Relationship Between Muscle Mass and Carbohydrate Intake Among Forwards on the "Tigres Rugby Club" U15 and U16 Teams, San Lorenzo 2025.

Ingesta de HC	Masa Muscular		TOTAL	p=0,35 (*)
	Adecuado	Déficit		
Adecuado	2	0	2	
Inadecuado	18	8	26	
TOTAL	20	8	28	

*Test de Fisher

Discussion and Conclusions

When the players are categorized by age group, it is observed that 49% (n=26) belonged to the U15 division and 51% (n=27) to the U16 division. This similar distribution between the two divisions is desirable because it matches the minimum number expected to form a rugby roster that includes both starters and substitutes.

In terms of playing position, forwards accounted for 53% (n=28) of the total, compared with 47% (n=25) for backs. This result is consistent with the typical on-field formation, where most players tend to be positioned as forwards—a strategic balance, as forwards provide the necessary stability in static phases of the game, such as the scrum and the lineout, while the backs demonstrate speed and agility in dynamic phases (13).

Table 1 shows that, for most players in both divisions and positions, the median MA (kg) values fell within the reference range according to URBAREF for youth. However, maximum values above the standard were observed. These results are consistent with those reported in the study by Gayol Flores, M., and Sillero Quintana, M. (2019), who also found subgroups of adult players with MA levels higher than recommended; this could compromise performance on the field (14).

As for the mean MM (kg), a large proportion of the players fell within the reference ranges. However, when analyzing minimum values, M15 backs and forwards from both divisions were identified as having below-average results; a situation similar to that described in the study by Báez-San Martín, E., et al. (2019); which could interfere with the development of the strength and power required for each position (15).

It is worth noting that the forwards in both divisions had higher mean values for MA (kg) and MM (kg) compared to the backs. This difference is consistent with the results obtained in adult players in studies conducted by Báez-San Martín, E., et al. (2019) and Hernández Camacho and Rodríguez Bies (2020), who note that forwards tend to have greater body mass than backs, in response to the demands for contact and strength inherent to their position (15,16).

On the other hand, when comparing across age groups, it was found that the U16 players had higher medians for MA (kg) and MM (kg) than the U15 players. This result could be related to each player's biological maturation process and the growth typical of adolescence (17).

Table 2 shows that 64% (n=34) of the players evaluated had MA values within the URBAREF youth reference ranges according to Francis Holway (n.d.); This compliance was primarily seen among backs in the U15 division at 19% (n=10), followed by forwards in both divisions at 17% (n=9), respectively.

On the other hand, the remaining 36% (n=19) showed an excess of this trait, primarily among forwards in the U-16 division (13%, n=7), followed by backs in the same category (9%, n=5). The greater tendency of forwards to accumulate MA is consistent with the findings of Báez-San Martín, E., et al. (2019), who point out that the characteristics specific to this position—related to size and strength—are often accompanied by greater body mass. However, as Hernández Camacho and Rodríguez Bies (2020) point out, when there is a significant excess of MA, it can affect a player’s power, speed, and agility, which would directly impact performance on the field (15,16).

Table 3 shows that the majority of the players evaluated—83% (n=44)—had adequate MM values, according to the URBAREF youth reference values. The largest percentage was accounted for by the backs in both divisions, at 24% (n=13) and 21% (n=11), respectively.

However, 17% (n=9) of the players showed a MM deficit, primarily among U-16 forwards, at 13% (n=7). This finding is striking because this position requires a greater amount of skeletal muscle to meet the demands for strength and power inherent in the game. A similar result was reported in the study by Báez-San Martín, E., et al. (2019), who identified adult forwards with lower-than-expected muscle development. Similarly, variations in the timing of puberty could explain why some players have not yet reached the peak of muscle gain typical of adolescence (15,17).

Table 4 shows the medians for caloric intake, carbohydrates, protein, and fat. With regard to caloric intake, the median value obtained for the players fell within the recommended ranges for the youth population according to the IOM (2002). However, when taking data variability into account, it became evident that the backs in both divisions had energy intakes higher than those recommended for their playing positions, while the forwards had energy intakes lower than those recommended for their positions. Compared with previous studies on adult players by Barale and Perovic (2014) and Posthumus et al. (2021), the caloric intakes of this sample of male youth athletes are lower, which is to be expected given the difference in age group and competitive level (18,19).

Regarding carbohydrate intake, the medians were found to be below the recommendations for youth rugby according to Onzari (2021); this was particularly true for forwards in both divisions, a situation that could compromise energy availability during practices and games, as well as interfere with growth and recovery (12).

In contrast, the median protein intakes were in line with the recommendations for youth rugby established by Onzari (2021), and even exceeded this value, especially among the backs in both divisions; this finding is similar to that reported in the study by Gayol Flores, M., and Sillero Quintana, M. (2019). Although this intake promotes growth and recovery, low carbohydrate intake could limit its anabolic effects (12,14).

Finally, it was observed that the median carbohydrate intake (in grams) far exceeded the recommendations for youth rugby established by Onzari (2021) for all players evaluated, consistent with findings in amateur adults; this could explain the high proportion of players with excessive carbohydrate intake in this sample.

Table 5 shows that 62% (n=33) of the athletes evaluated had an adequate caloric intake according to the recommendations for adolescents (IOM, 2002), which is a favorable result in terms of meeting the energy requirements associated with growth and athletic training. However, 23% (n=12) showed excessive caloric intake, concentrated mainly among the backs in both divisions at 13% (n=7) and 6% (n=3), respectively, which could be linked to the frequent consumption of ultra-processed foods and sugar-sweetened beverages; a finding that is consistent with the observations of Gayol Flores, M., and Sillero Quintana, M. (2019) and Hernández Camacho and Rodríguez Bies (2020) regarding adult players (14,16).

In contrast, 15% (n=8) of the players had an insufficient caloric intake, primarily among the forwards in both divisions, at 4% (n=2) and 9% (n=5), respectively. This finding was concerning, as energy deficiency could limit growth and recovery, as well as explain the skeletal muscle mass deficit observed in forwards in the U16 division; which is consistent with the findings of Onzari (2021), who emphasizes that in amateur youth categories, the typical diet is often insufficient to support both growth and development as well as the specific energy demands of rugby (12).

Table 6 shows that 73% (n=39) of the players evaluated had an insufficient carbohydrate intake relative to the recommendations for youth rugby according to Onzari (2021), a situation that is more prevalent among forwards in both divisions, at 30% (n=16) and 19% (n=10), respectively.

This finding is significant because carbohydrates are the primary source of energy in high-intensity intermittent sports such as rugby, and a deficiency in carbohydrates could not only compromise performance during training and games but also limit recovery and skeletal muscle development (5,14). This finding is consistent with the results reported in studies of adult players by Barale and Perovic (2014) and Posthumus et al. (2021), where low HC contributions were also observed, especially among forwards (18,19). However, among adolescents, this deficiency becomes even more significant, as it compounds the demands inherent in growth and pubertal maturation (17).

Table 7 shows that 36.5% (n=19) of the players—primarily backs from both divisions, accounting for 19% (n=10) and 7.5% (n=4), respectively—had an excessive intake of this substance. This finding is consistent with the results reported for adult players by Barale and Perovic (2014) and Gayol Flores, M., and Sillero Quintana, M. (2019), who found that backs tend to consume more protein than forwards (14,18). While a higher protein intake could support recovery processes, in this context it may be displacing carbohydrate intake, which was found to be insufficient in most players. This imbalance could affect energy availability during training sessions and games, as well as limit the anabolic utilization of proteins (20).

Table 8 shows that 96% (n=51) of the players evaluated had a carbohydrate intake in grams that exceeded the recommendations for youth rugby according to Onzari (2021), with no significant differences between divisions or playing positions. This finding is similar to that of the study by Gayol Flores, M., and Sillero Quintana, M. (2019), who identified excessive fat intake among some adult players; which could lead to reduced performance on the field, an increase in body fat at the expense of muscle mass, long-term metabolic risks, and a displacement of specific nutrients such as fiber, minerals, and vitamins (5,20).

Figure 2 shows the average frequency of regular consumption of the main food groups reported based on the three R24s. The results show that, with regard to foods that are sources of carbohydrates, most of the players (94%; n=50) included bread in their diet, and 92% (n=49) consumed grains and grain products such as rice, pasta, and semolina during the days evaluated. As for vegetables, consumption of those in Group C—especially potatoes and corn—was most common, at 81% (n=43), followed by those in Group A, such as spinach, lettuce, and tomatoes, at 74% (n=39). Meanwhile, fruit consumption was reported in 77% of cases (n=41). However, it should be noted that, as with grains, fruit and vegetable consumption was concentrated mainly on a single day out of the three evaluated. On the other hand, the consumption of sugary beverages stands out, with soft drinks accounting for 68% (n=36) and artificial juices for 34% (n=18).

With regard to protein-rich foods, those from AVB were the most common. 100% (n=53) of the players reported consuming dairy products, including milk, yogurt, and cheese; it is worth noting that most of them consumed these products on all three days of the study. Similarly, 100% (n=53) reported eating meat—primarily beef and chicken—on two or three of the days evaluated. In addition, 94% (n=50) included eggs in their diet.

With regard to foods that are sources of Grs, it is noteworthy that 92% (n=49) of the players consumed fast food on at least one of the days evaluated, such as empanadas, pizza, lomito or milanesa sandwiches, and hamburgers. Similarly, 72% (n=38) consumed lard, and 68% (n=36) included ham in their diet. It was also noted that 83% (n=44) chose sweets for their snack, with alfajores, chocolates, and sweet cookies being the most popular choices.

Overall, these results reflect a dietary pattern similar to that described by UNICEF (2020) among adolescents, characterized by high consumption of foods rich in fats and simple sugars and low intake of fruits, vegetables, and complex carbohydrates (5). This

profile could help explain the findings regarding the players' body composition, particularly their excess body fat and low muscle mass. The prevalence of ultra-processed foods in the diet could displace the consumption of fresh foods with higher nutritional density, limiting the availability of nutrients essential for growth and recovery, as well as promoting the accumulation of fat mass at the expense of muscle mass.

These findings are consistent with those reported in studies conducted on adult amateur players (Gayol Flores, M., and Sillero Quintana, M., 2019; Báez-San Martín, E., et al., 2019). However, they are particularly important among young people, whose eating habits are still developing and can influence both athletic performance and health in adulthood.

Table 9 shows the relationship between MA and caloric intake among backs in both divisions. Although the Fisher's exact test yielded a p-value of 0.09, which was not statistically significant, it was observed that among the players with adequate caloric intake (n=14), half of them had excess body fat (n=7), while the other half (n=7) fell within the reference ranges. In contrast, among players with inadequate caloric intake (n=11), most maintained an adequate MA (n=9), while only a minority had an excess MA (n=2).

Table 10 shows the relationship between average weight and caloric intake among forwards in both divisions. Although the p-value of 0.06 is not statistically significant either, it was observed that among players with adequate caloric intake, nearly half had an excess of MA (n=9), while the other half maintained an adequate MA (n=10). In contrast, among players with inadequate caloric intake, most had an adequate MA (n=8), and only one player had an excessive MA (n=1).

These results indicate that, as with the backs, excess body mass does not appear to be related solely to the number of calories consumed, but also to food choices and macronutrient distribution, as well as variability in growth and pubertal maturation. This is consistent with the findings of Onzari (2021), who states that for adolescents, it is not enough to simply adjust caloric intake to meet their requirements; rather, priority should be given to the quality and proportion of nutrients (12). Similarly, the results are consistent with those described by Gayol Flores, M., and Sillero Quintana, M. (2019) in adult amateur athletes, where excess body fat is more closely related to the types of foods consumed than to total dietary energy intake.

Table 11 shows the relationship between MA and gram intake among the backs in both divisions. Given that the p-value of 0.16 did not indicate statistical significance, it can be observed that although all players in this position (n=25) had an inadequate intake of Grs due to excess consumption, the majority maintained MA values within the appropriate range (n=16). However, there were also players identified who had excessive levels of it (n=9).

Table 12 analyzes the relationship between MA and Grs intake among forwards in both divisions. As with the backs, although most of the forwards (n=26) had an inadequate intake of Grs due to excess consumption, a large proportion of them had an adequate MA (n=17). However, a considerable number of cases with elevated levels were also identified (n=9). Statistical analysis (p=0.66) did not reveal a significant association, but the data are consistent with what was previously observed in the total sample.

These results reinforce the notion that the amount of grams consumed far exceeds the recommended values for youth rugby, and that this excess does not always directly translate into increased body fat. Factors such as high energy expenditure during training, variability in pubertal maturation, and overall diet quality may explain why some players with excessive protein intake did not show excess body fat (17).

Table 13 analyzes the relationship between MM and protein intake among backs in both divisions. The Fisher's exact test yielded a p-value of 0.36, which was not

statistically significant. Even so, the data showed that most players had an adequate MM (n=24), regardless of whether or not they had an adequate protein intake. This result could be explained by the expected protein intake of 1.2 to 2 g/kg/day, as well as by the growth and maturation phase characteristic of adolescence, during which protein intake naturally increases.

Table 14 shows the relationship between body mass and protein intake among forwards in both divisions. The p-value of 0.63 indicated that there is no statistically significant association. However, it was observed that most players with adequate protein intake (n=23) had a body mass index (BMI) within the reference range (n=16), although several cases of deficiency were recorded (n=7). Among those who had an inadequate protein intake due to excessive intake (n=5), the majority still maintained an adequate body mass index (n=4).

As with the backs, these results suggest that protein intake, on its own, does not appear to directly explain the players' muscle mass. This is consistent with the findings of Onzari (2021), who notes that, once protein requirements are met, excess protein does not have an additional effect on muscle development, especially if there is a deficit in carbohydrate intake that forces the body to use protein as an energy source. Furthermore, as noted by Torresani (2022) regarding adolescents and by Báez-San Martín, E., et al. (2019) In adults, the development of muscle mass depends not only on protein intake but also on total energy availability, carbohydrate consumption that allows protein to be conserved for anabolic functions, and each player's stage of biological maturation.

Table 15 shows the relationship between body mass and carbohydrate intake among backs in both divisions. Although the p-value of 0.24 does not indicate statistical significance, it is observed that most players had an adequate MM (n=24), even though a large proportion of them had an inadequate HC intake due to insufficiency (n=14). These results suggest that, in this sample, there is no direct relationship between body mass and HC intake. However, it is important to note that carbohydrates are the primary energy substrate during physical exertion, and that insufficient intake may force the body to use protein as an energy source, reducing its availability for muscle synthesis (12).

Table 16 shows the relationship between body mass and carbohydrate intake among forwards in both divisions. The statistical analysis with p = 0.35 did not indicate a significant association. However, nearly all players had an inadequate carbohydrate intake due to insufficient intake (n=26), and within this group, the majority maintained adequate muscle mass levels (n=18); although some players were also found to have a muscle mass deficit (n=8). In contrast, the few players with adequate carbohydrate intake had MM values within the expected range (n=2).

As with the backs, the high proportion of players with adequate muscle mass despite insufficient carbohydrate intake (n=18) could be linked to factors such as age and the growth stage typical of adolescence, as well as training volume, which stimulate muscle development even under suboptimal nutritional conditions (17). However, the number of players with deficits (n=8) highlights the risk of maintaining this condition in the long term, as it could limit their ability to generate strength and power—key aspects for this position. These results are consistent with those reported in studies of adults by Báez-San Martín, E., et al. (2019), who emphasize that an insufficient intake of carbohydrates can compromise muscle mass even in athletes with adequate protein intake.

Conclusions

The distribution of players was similar in both divisions, with forwards making up the majority.

With regard to body composition, most players were found to have an appropriate body mass (kg). However, there were instances of overuse, particularly among M16 users. On the other hand, when considering body mass (kg), most of the adolescents evaluated were found to be within the normal range, although some forwards on the U-16 team were below the normal range.

With regard to dietary intake, the players generally had an adequate caloric intake, but there were cases of backs with excessive energy intake and forwards with insufficient caloric intake.

With regard to macronutrient distribution, the study highlighted insufficient carbohydrate intake among the majority of players, who had a limited variety of fruits and vegetables in their diets. In addition, excessive protein intake was observed, mainly among the backs, with a diet consisting of high-protein foods; and higher-than-expected fat intake among most participants, with a diet consisting of foods high in saturated fats such as alfajores, facturas, buns, butter, and fried foods, among others.

Upon analyzing the relationship between body composition and food intake, no statistically significant association was found; therefore, the proposed hypothesis is rejected. However, the results indicated that excess body fat and the development of metabolic syndrome are not determined solely by the number of calories consumed, but also by the quality of food choices, macronutrient distribution, and factors specific to the players' stage of growth and pubertal maturation.

Proposals for Continuity

Conduct studies that include the players' maturational or biological age as a variable, since it is a key factor in body composition during this growth stage.

Expand the sample to include different clubs or categories in order to enrich the analysis and prevent the results from being limited to a single club or cohort, thereby promoting a more comprehensive view of body composition and dietary intake throughout the training process.

Conduct a longitudinal study that takes into account the different stages of the season, which would allow for an assessment of changes in body composition and food intake during the preseason, competition, and postseason, given that energy demands vary depending on the time of the athletic year.

Implement nutrition education workshops for players, families, guardians, and coaches, with the aim of promoting healthy habits that support the athletic and personal development of adolescent players.

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Conflict of Interest

It is hereby declared that there is no conflict of interest.

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Footprint Analysis in Children Aged 5 to 11 Years: A Study in the City of Quito

Análisis de la Huella Plantar en Niños de 5 a 11 Años: Estudio en la Ciudad de Quito

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ABSTRACT

Introduction: Footprint and posture analysis in children is a highly relevant topic in podiatry and biomechanics, as it allows for the identification of alterations that can directly influence motor development, gait, and consequently, future quality of life. In the city of Quito, there are no previous studies that specifically address this issue, highlighting the need to generate local data to understand the behavior of children's feet in this population and, in turn, contribute evidence to the national scientific community. Methods: This study was designed as a descriptive and exploratory investigation with a quantitative design, aimed at collecting data that explain variations in gait pattern through the application of pedigraphic tests in children between 5 and 11 years old. Results: The results show that 70 participants presented with cavus feet, representing 66.67% of the sample; while 20 children, equivalent to 19.04%, exhibited flat feet. Fifteen participants, representing 14.28%, presented with a normal or neutral foot. Discussion These findings reflect a marked predominance of cavus feet within the studied population, followed by a smaller percentage of flat feet, highlighting particular morphological patterns that require greater professional and scientific attention. Taken together, these results underscore the importance of continuing to investigate and promote frequent podiatric evaluations in children to identify early alterations and guide timely interventions.

RESUMEN

Palabras clave:

Introducción: El análisis de la huella y la postura del pie en niños es un tema de gran relevancia dentro de la podología y la biomecánica, ya que permite identificar alteraciones que pueden influir directamente en el

huella plantar, población pediátrica, pie cavo, pedigrafía	desarrollo motor, la marcha y, en consecuencia, en la calidad de vida futura. En la ciudad de Quito no existen estudios previos que aborden esta problemática de manera específica, lo que resalta la necesidad de generar información local que permita comprender el comportamiento del pie infantil en esta población y, a su vez, aportar evidencia para la comunidad científica nacional. Método: El estudio realizado se planteó como una investigación de tipo descriptivo y exploratorio, con un diseño cuantitativo, orientado a recopilar datos que expliquen las variaciones en la forma de la pisada mediante la aplicación de pruebas de radiografías en niños entre 5 y 11 años. Resultados: Los resultados obtenidos muestran que 70 participantes presentaron pie cavo, lo que representa el 66.67% de la muestra; mientras que 20 niños, equivalentes al 19.04%, evidenciaron pie plano; y 15 participantes, correspondientes al 14.28%, presentaron un pie normal o neutro. Discusión: Estos hallazgos reflejan una marcada predominancia del pie cavo dentro de la población estudiada, seguido por un porcentaje menor de pie plano, lo que evidencia patrones morfológicos particulares que requieren mayor atención profesional y científica. En conjunto, estos resultados subrayan la importancia de continuar investigando y promoviendo evaluaciones podológicas infantiles frecuentes para identificar alteraciones tempranas y orientar intervenciones oportunas.

Introduction

Foot development during childhood is significant from both a clinical and biomechanical perspective, since between the ages of 5 and 11, structures essential for locomotion, body weight support, and postural stability become established. This growth phase is a critical time in the development of the arch of the foot and, consequently, in the prevention of conditions such as flat feet or high arches, which could lead to orthopedic and functional complications later in life.

Internationally, numerous studies have examined the association between foot prints and body posture (1), evaluating the relationship between foot prints and body posture in a school population using the Hernández Corvo Index (IHC) and the Portland State University (PSU) method. They reported that 10% of the students had flat feet and found significant differences in posture based on gender. They also identified a moderate correlation between body mass index (BMI) and shoulder-to-waist ratio (1). In another study, Stefan et al. noted that lower levels of physical activity are associated with increases in plantar pressure, as well as longer contact time and higher peak and average pressure values. These findings indicate that physical activity plays a significant role in the biomechanics of the foot in children aged 6 to 14 years(2).
In Ecuador, regional studies have been conducted that provide relevant data and highlight the need to explore this topic in greater depth. In the article Abnormalities in Footprints Among Preschoolers at the "Francisco Chiriboga" Buen Vivir Children's Center, the authors described a high prevalence (93%) of abnormalities in footprints among preschoolers in Riobamba. In addition, 53% had physiological flat feet (3).
Similarly, in the context of secondary research at the national level, a study conducted in Cuenca among children aged 10 to 15 years showed a prevalence of pes cavus (56% in the right foot and 45.3% in the left), as assessed using a photopodometer and the Hernández Corvo index. These findings indicate that morphological variations in the foot are not only common but can also vary significantly by age, gender, or body mass index (BMI) (4).
Despite these advances in other cities, there are no previous studies in Quito that address this issue, making it necessary to generate specific information for this population and to contribute to the scientific community in the future. Given the capital city's high altitude (about 2,850 m), unique environmental, nutritional, and socioeconomic factors may influence children's biomechanics, including both their footprints and foot posture.
Footprint analysis is essential because it provides insight into the interaction between foot morphology and the distribution of body weight. Thus, correlations can be identified between foot deformities (flat feet or high arches) and postural abnormalities in the knees, ankles, or hips. This type of holistic approach is valuable for developing evidence-based preventive strategies focused on the use of appropriate footwear, educational programs for parents and teachers, or early physical therapy interventions among school-age populations in Quito.
Currently, in clinical practice, it is very common to find certain biomechanical abnormalities in children's feet, with flat feet being one of the most common. During well-child visits, the physical assessment of a pediatric patient's gait often goes unnoticed; this is why a proper analysis of the footprint is so important in this age group.
The study of the footprint and foot posture in children is a highly significant aspect of podiatry and biomechanics, as it facilitates the early detection of postural abnormalities that could affect motor development and long-term quality of life (5).
The primary objective of this study is to evaluate foot morphology and possible postural abnormalities in children in the city of Quito, with the aim of gathering information that

will contribute to the prevention of musculoskeletal disorders from an early age and, thereby, reduce the risk of future complications.
The significance of this research lies in the need for early and comprehensive identification of potential abnormalities in gait and foot support, as these can affect physical performance and contribute to the development of conditions such as flat feet, high arches, or other abnormalities, including limb length discrepancies (6).
In addition, factors that may affect foot posture—such as the type of footwear, the level of physical activity, and genetic factors—are taken into account (7). Based on this theoretical framework, the aim is to generate meaningful information for both the scientific community and health professionals working to prevent postural disorders in children.

Biomechanics of the Footprint and Foot Alignment

During early childhood, particularly between the ages of 5 and 11, the foot undergoes a fundamental process of maturation, both structurally and functionally. During this period, the bones, muscles, and ligaments gradually strengthen, which contributes to the formation of the medial longitudinal arch and the development of a more stable gait pattern (Pita-Fernández et al., 2022). Physiological flat feet, which are common during the early years of life, usually resolve on their own around the age of 7 or 8. However, in certain cases, these changes may persist over time and lead to postural compensations that affect other parts of the body, such as the knees, hips, and spine (Rojas Vega & Gutiérrez, 2020).

A study conducted in Ecuador, which included a sample of 1,678 children, demonstrated significant annual variations in foot dimensions, such as length (with increases of up to 4.7–5.0%) and width (between 3.8–3.9%).

Similarly, the arch of the foot showed an annual increase of 1.5% in girls and up to 4% in boys between the ages of 5 and 6. A high prevalence of flat feet was also observed, particularly among 8-year-old girls (64.9%) and 12-year-old boys (82.5%) (Martín, Palomo et al., 2024).

This finding highlights the need to take age and gender into account in population-based research, and suggests that in Quito, due to its altitude and unique characteristics, these patterns may manifest specifically among children.

A footprint represents the pattern of contact between the foot and the ground and is a useful diagnostic tool for identifying morphological abnormalities such as flat feet, normal feet, and high arches. Footprint analysis allows for an assessment of the development of the arch of the foot, body weight distribution, and symmetry of weight bearing. There are various methods for studying this, including the Hernández Corvo index and the Chippaux-Smirak index, which are widely used in clinical and school-based studies (Villanueva et al., 2019). Early identification of abnormalities in the footprint can help prevent chronic postural imbalances and locomotor disorders.

Foot posture refers to the foot's three-dimensional alignment during weight-bearing. It is generally classified as neutral, pronated, or supinated. Poor alignment can affect overall body mechanics, leading to compensatory changes in structures such as the ankles, knees, pelvis, and spine. For example, excessive pronation is associated with flat feet, while supination is linked to high arches (Zapata Sánchez et al., 2020). During early childhood, these abnormalities often go unnoticed; however, if they are not corrected in a timely manner, they can lead to biomechanical disorders during adolescence and adulthood.

A healthy foot is essential for good posture and walking. Flat feet is a medical condition characterized by the absence or reduction of the medial longitudinal arch, accompanied by osteoligamentous misalignment. Because of the plantar fat pad, a baby's

feet appear flat; this fat pad disappears between the ages of 2 and 10 as the medial arch develops. (Abich, 2020).

The anatomical manifestations of flattening or descent of the medial arch of the foot include ligament laxity, equinus deformity, torsional deformity, vertical talus, and tarsal coalition, caused by multifactorial variables such as being overweight, obesity, footwear type, weakness of the muscles supporting the arch, foot injuries, and congenital deformities. (Abich, 2020)

Although flat feet and high arches have opposite morphological characteristics, both can impair foot function and affect a child's overall posture. These variations in the arch of the foot lead to changes in weight distribution, balance, and gait mechanics, which can result in compensatory changes in other structures such as the knees, hips, or spine. For this reason, it is important to consider both types of abnormalities within the same analytical framework, since their timely detection allows for an appropriate and case-specific intervention.

pes cavus is an orthopedic condition that affects both children and adults. Pes cavus is a deformity typically characterized by cavus (elevation of the longitudinal arch of the foot), plantar flexion of the great toe, pronation of the forefoot, and valgus or varus of the hindfoot and adduction of the forefoot. (Travis & Bola, 2023). And it may be the result of a forefoot propulsion disorder.

Various factors influence the shape of the foot and foot posture in children. Age is a key factor, since the development of the arch of the foot and postural stability gradually become established as the child grows. Gender may also play a role, as significant differences in the prevalence of flat feet between boys and girls have been observed in some populations (Burbano & Viteri, 2018). Furthermore, being overweight and obesity have been associated with a higher incidence of postural and morphological abnormalities of the foot, due to the increased load on structures that are not yet fully developed (Zapata Sánchez et al., 2020). Finally, the geographical environment and the type of footwear can have a significant impact: walking barefoot on natural surfaces promotes the development of the arch of the foot, while prolonged use of inappropriate footwear can limit it (Muñoz-Chávez et al., 2023).

In the city of Quito, located more than 2,800 meters above sea level, children grow up in a unique geographic and socioeconomic environment. Differences in climate, culture, and access to health care can influence the physical growth and movement patterns of children. However, there are only a limited number of studies that jointly analyze footprints and foot posture in this specific population. Therefore, this study aims to contribute to local knowledge about pediatric biomechanics, generate useful information for the prevention of musculoskeletal disorders, and guide future interventions in the fields of public health, physical education, and pediatric physical therapy.

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A footprint represents the pattern of contact between the foot and the ground and is a useful diagnostic tool for identifying morphological abnormalities such as flat feet, normal feet, and high arches. Footprint analysis allows for an assessment of the development of the arch of the foot, body weight distribution, and symmetry of weight bearing. There are various methods for studying this condition, including the Hernández Corvo index and the Chippaux-Smirak index, which are widely used in clinical and school-based studies(10). Early identification of abnormalities in the footprint can help prevent chronic postural imbalances and locomotor disorders.

Foot posture refers to the foot's three-dimensional alignment during weight-bearing. It is generally classified as neutral, pronated, or supinated. Poor alignment can affect overall body mechanics, leading to compensatory changes in structures such as the ankles, knees, pelvis, and spine. For example, excessive pronation is associated with flat feet, while supination is linked to high arches (11). During childhood, these abnormalities often go unnoticed; however, if they are not corrected in a timely manner, they can lead to biomechanical disorders during adolescence and adulthood.

A healthy foot is essential for good posture and walking. Flat feet is a medical condition characterized by the absence or reduction of the medial longitudinal arch, accompanied by osteoligamentous misalignment. Because of the plantar fat pad, a baby's feet appear flat; this fat pad disappears between the ages of 2 and 10 as the medial arch develops(12).

The anatomical manifestations of flattening or descent of the medial arch of the foot include ligamentous laxity, equinus deformity, torsional deformity, vertical talus, and tarsal coalition, caused by multifactorial variables such as being overweight, obesity, footwear type, weakness of the muscles supporting the arch, foot injuries, and congenital deformities (12).

Although flat feet and high arches have opposite morphological characteristics, both can impair foot function and affect a child's overall posture. These variations in the arch of the foot lead to changes in weight distribution, balance, and gait mechanics, which can result in compensatory changes in other structures such as the knees, hips, or spine. For this reason, it is important to consider both types of abnormalities within the same analytical framework, since their timely detection allows for an appropriate and case-specific intervention.

Pes cavus is an orthopedic condition that affects both children and adults. Pes cavus is a deformity typically characterized by cavus (elevation of the longitudinal arch of the foot), plantar flexion of the first toe, pronation of the forefoot, and valgus and varus of the hindfoot, as well as adduction of the forefoot (13). And it may be the result of a forefoot propulsion disorder.

Various factors influence the shape of the foot and foot posture in children. Age is a key factor, since the development of the arch of the foot and postural stability gradually become established as the child grows. Gender may also play a role, as significant differences in the prevalence of flat feet between boys and girls have been observed in

some populations (14). Furthermore, being overweight and obesity have been associated with a higher incidence of postural and morphological abnormalities of the foot, due to the increased load on structures that are not yet fully developed (11). Finally, the geographical environment and the type of footwear can have a significant impact: walking barefoot on natural surfaces promotes the development of the arch of the foot, while prolonged use of inappropriate footwear can limit it (15).

In the city of Quito, located more than 2,800 meters above sea level, children grow up in a unique geographic and socioeconomic environment. Differences in climate, culture, and access to health care can influence the physical growth and movement patterns of children. However, there are only a limited number of studies that jointly analyze footprints and foot posture in this specific population. Therefore, this study aims to contribute to local knowledge about pediatric biomechanics, generate useful information for the prevention of musculoskeletal disorders, and guide future interventions in the fields of public health, physical education, and pediatric physical therapy.

Method

In Ecuador, regional studies have been conducted that provide relevant data and highlight the need to explore this issue in greater depth, particularly in the capital city. In the article Abnormalities in Footprints Among Preschoolers at the "Francisco Chiriboga" Buen Vivir Children's Center, the authors described a high prevalence (93%) of abnormalities in footprints among preschoolers in Riobamba (3).

However, it is the only city to have reported a study on this topic, which is why there is a need to assess the plantar footprint in children living in Quito, given that the demographic and socioeconomic characteristics differ.

This study is descriptive and exploratory in nature, with a quantitative design. The study focused on finding information to support and explain why there are variations in foot strike patterns, based on pedigraphic tests conducted on children aged 5 to 11.

To obtain the children's footprints, the baropodometric analysis method was used with a pedigraph, a simple and effective instrument used in clinical, educational, and sports settings to produce a graphical representation of the footprint. Its main function is to record the shape of the foot in a static position, allowing for the observation of the type of foot arch and the detection of possible morphological abnormalities such as flat feet, high arches, or asymmetries between the two feet. It captures the footprint, from which various measurements were taken and a mathematical formula was applied; this formula, using a percentage (%), helps identify potential abnormalities in the structure or function of the foot.

The analysis of the footprint obtained using a pedigraph provides relevant information about load distribution, the degree of contact in the forefoot, midfoot, and hindfoot regions, as well as the condition of the arch of the foot. It also makes it easier to track the progress of orthopedic treatments or therapeutic exercise programs over time. Although it does not provide dynamic data like that offered by a baropodometric platform, the pedigraph remains a useful and valid tool, especially in school settings or communities

with limited access to specialized technology.

In addition, a physical assessment was conducted to observe and analyze foot posture, taking into account factors such as the alignment of the feet and legs, as well as to identify flat feet, high arches, or neutral feet.

Results

Of the 105 participants, 49 children—equivalent to 46.67%—were between the ages of 5 and 7, while 56 children—equivalent to 53.33%—were between the ages of 8 and 11 (Figure 1).

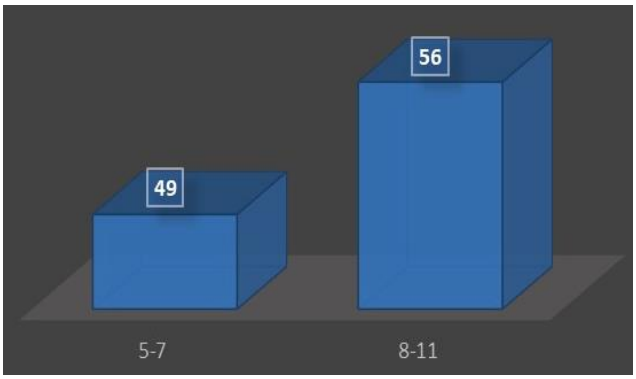

Figure 1. Age ranges.

Based on the graph, pes cavus is more common in older age groups.

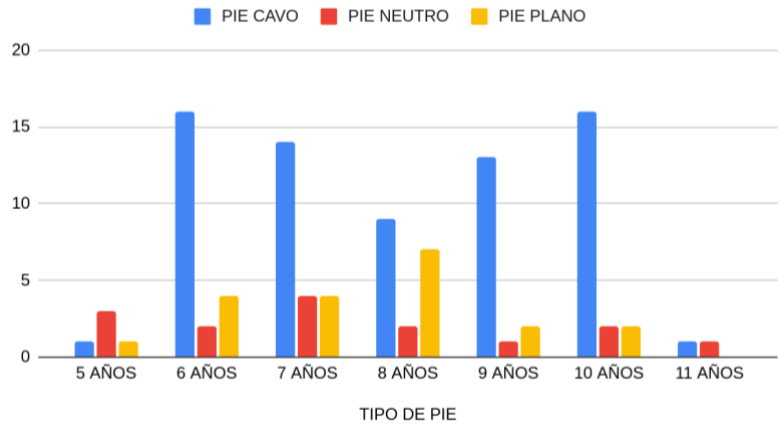

Figure 2. Foot Type by Age

In terms of gender, it is evident that 80 of the participants—equivalent to 76.19%—were male, while 25 participants—representing 23.81%—were female, indicating a notable difference in this regard (Figure 2).

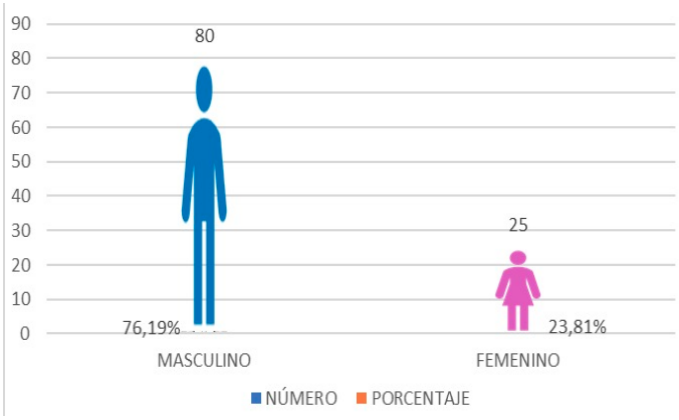

Figure 3. Percentage of participants by gender.

With regard to the participants' gender, the results show that high arches are more common among women: 17 women had high arches, accounting for 68%; 4 women had normal arches; and 4 others had flat feet, accounting for 16% respectively. (Figure 3)

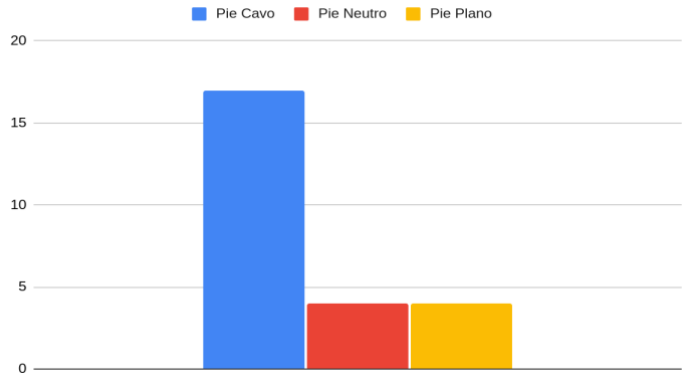

Figure 4. Foot Type in Relation to Females

Regarding foot shape in males, 77 individuals were found to have high arches, representing 65%; 11 individuals had normal arches, representing 13.75%; and 17 individuals had flat feet, representing 21.25%. (Figure 4).

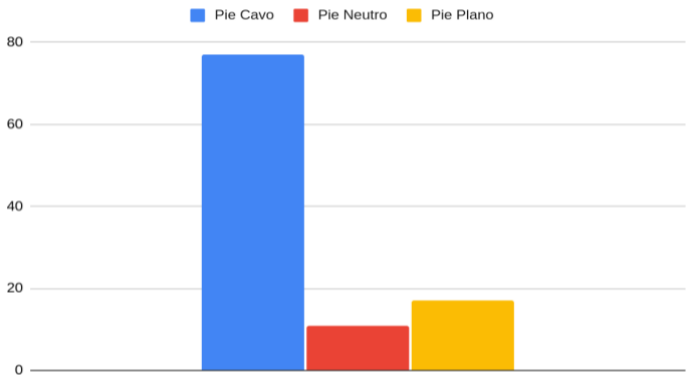

Figure 5. Foot Shape in Relation to Males

With regard to foot type, 70 participants had high arches, accounting for 66.67%; 20 children, or 19.04%, had flat feet; and 15, or 14.28%, had normal or neutral feet. In this group, the majority of participants show very pronounced signs of high arches, while a smaller group exhibits flat feet (Figure 5).

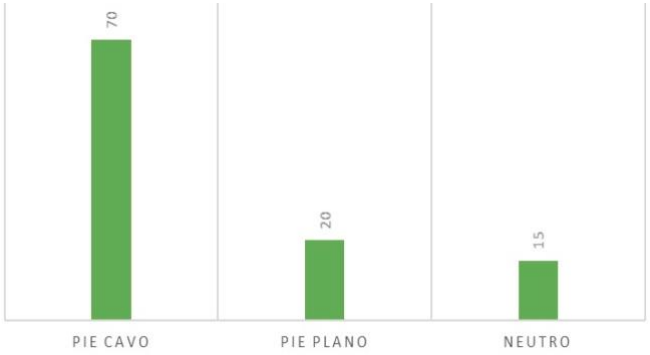

Figure 6. Number of participants by foot type.

Discussion and Conclusions

Studies on foot type in certain regions of Ecuador are scarce and limited; therefore, this review aims to identify the prevalence of foot type by age and sex. The results show a marked prevalence of high arches over flat feet in both men and women; this is supported by the studies mentioned earlier in this article, which showed that high arches are more common in areas geographically similar to Zámbiza.

The neutral foot type shows lower percentages than the other foot types, which indicates that high arches are more common in this age group in this region and may be more closely related to factors such as weight, physical activity, and the patient's age.

Given that similar results were observed in both females and males, we can conclude that there is no direct relationship between sex and foot type, since, in this study group, pes cavus was present in more than 60% of both the female and male groups.

Among children aged 6 to 10, there is a marked tendency for high arches to be more common than flat feet and neutral feet; among children aged 5 to 6, flat feet predominate, since in early childhood the human foot goes through stages of morphofunctional maturation. As mentioned earlier, the bones, muscles, and ligaments of the foot gradually strengthen to form the medial longitudinal arch.

Identifying these structural variations in the feet is important, as they provide information about the potential long-term consequences this population may face if corrective measures are not taken. Based on the studies reported in this review, the consequences that may arise are as follows: pain that may be diffuse in the feet, ankles, or legs, or even specific pain in the sole of the foot that worsens with movement; fatigue in the feet after standing, walking, or engaging in sports for an extended period; changes in gait that are evident through asymmetric wear on footwear and that, in turn, indicate uneven weight distribution.

Podiatric care and foot print analysis in children are essential for the early detection of abnormalities in arch development and foot biomechanics, which can affect posture, gait, and physical performance throughout childhood. A timely evaluation can help identify conditions such as flat feet or high arches, which, if left untreated, could lead to discomfort, muscle compensations, and future complications. Based on the above, pediatric podiatric care contributes to the early detection of conditions and provides guidance to parents or caregivers on the proper use of footwear, healthy habits, and preventive measures, thereby ensuring optimal motor development and reducing the risk of functional problems later in life.

A study analyzing the foot prints of children aged 5 to 11 in the city of Quito revealed a high prevalence of pes cavus in most of the age groups evaluated, making it a morphological abnormality that requires attention in both pediatric and podiatric settings. This finding highlights the importance of understanding the development of the

arch of the foot in the local pediatric population, since the biomechanical characteristics of the foot during childhood can have a significant impact on posture, gait, and functionality later in life.

Similarly, the comparative analysis by sex revealed insignificant differences between boys and girls, with very similar percentages observed for the presence of pes cavus. This suggests that sex is not a determining predisposing factor in this sample, and that the identified trend may be more closely related to characteristics specific to the study population, as well as to possible environmental factors or common postural habits.

The findings provide relevant data for the implementation of preventive and control measures in the early stages. In this context, it is recommended to promote regular podiatric evaluations in schools, as well as to strengthen foot health education programs aimed at teachers, parents, and caregivers. Furthermore, it is essential to take this information into account to guide future research that explores associated variables, such as footwear type, physical activity level, family history, and the presence of concomitant musculoskeletal disorders.

Overall, this study expands our understanding of the behavior of the plantar arch in the pediatric population of Quito and highlights the need to implement measures to monitor and promote foot health from an early age. This will promote proper foot development and reduce the risk of future long-term biomechanical abnormalities.

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Conflict of Interest

The authors declare that they have no conflicts of interest, personal or financial, that could have inappropriately influenced the conduct, design, presentation, or interpretation of the results of this research.

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