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REVIEW

Effect of açai supplementation (*Euterpe Oleracea Mart.*) associated with exercise in animals and human: a scoping review

*Efeitos da suplementação com açaí (*Euterpe Oleracea Mart.*) associada ao exercício físico em animais e humanos: revisão de escopo*

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ABSTRACT

Objective

This scoping review aimed to map evidence on açai supplementation combined with exercise in animal and/or human experimental studies.

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Methods

The search considered six electronic databases and screening of relevant references. The selection process and data extraction were performed by two independent authors. The study characteristics, and AS (*e.g.*, form, intervention time, amount ingested) and exercise (*e.g.*, types, intensity, and duration) strategies were summarized, as well as their reported results.

Results

From an initial total of 342 studies identified; 11 (5 with animal and 6 with human models) were eligible. In animals, açai supplementation and exercise led to benefits in exercise tolerance and improvements in several hemodynamic parameters, as well as significant improvements in liver markers and glucose metabolism. In humans, açai supplementation indicated positive results in increasing exhaustion time to 90% of VO_{2max} and increasing intensity at the anaerobic threshold.

Conclusion

We conclude that future research involving animals and humans should examine açai supplementation and exercise with (a) obesity models to test the effect of adiponectin on body composition with analysis of histological and histochemical parameters; (b) eccentric injury protocols with the incorporation of muscle quality variables to assess recovery; (c) chronic açai supplementation and strength training; (d) comparison of different forms of açai supplementation in exercise protocols.

Keyword: Antioxidant. Glucose metabolismo disorders. Oxidative stress. Performance. Sport nutritional sciences.

RESUMO

Objetivo

Esta revisão de escopo teve como objetivo mapear evidências sobre a suplementação com açaí combinada com exercícios físicos em estudos experimentais em animais e / ou humanos.

Métodos

A busca considerou seis bases de dados eletrônicas além da triagem de referências relevantes. O processo de seleção e extração de dados foi realizado por dois autores independentes. As características do estudo, estratégias de suplementação de açaí (forma, tempo de intervenção, e quantidade ingerida) e exercícios (tipos, intensidade e duração), seus resultados foram resumidos.

Resultados

Um total de 342 estudos foram inicialmente alcançados e somente 11 foram elegíveis (5 com animais e 6 com humanos). Em animais, a suplementação de açaí e os exercícios indicaram benefícios na tolerância ao exercício e melhorias em vários parâmetros hemodinâmicos, bem como melhorias significativas nos marcadores hepáticos e no metabolismo da glicose. Em humanos, a suplementação de açaí indicou resultados positivos no aumento do tempo de exaustão para 90% do $VO_{2máx}$ e no aumento da intensidade correspondente ao limiar anaeróbio.

Conclusão

Concluiu-se que pesquisas futuras envolvendo animais e humanos devem examinar a suplementação de açaí e exercícios com (a) modelos de obesidade para testar o efeito da adiponectina na composição corporal por meio de parâmetros histológicos e histoquímicos (b) protocolos de dano muscular excêntrico com incorporação de variáveis de qualidade muscular para avaliação da recuperação; (c) suplementação crônica de açaí e treinamento de força; (d) comparação das diferentes formas de suplementação de açaí em protocolos de exercícios.

Palavras-chave: *Antioxidantes. Desordens no metabolismo da glicose. Estresse oxidativo. Desempenho. Ciências da nutrição esportiva.*

INTRODUCTION

The positive influence of regular exercise on a range of health benefits has been described in the literature, including a reduction in the risk of developing cardiovascular disease, cancer, and diabetes [1-3]. However, one of the concerns surrounding the performance of exercise, when performed for a long time or in an intense manner, is that it can generate an accumulation of Reactive Oxygen Species (ROS) and

Nitric Oxide (NO) [4]. Although recent studies indicate the importance of a certain level of stress for cellular adaptations to occur, in excess it can result in damage to cell structures, compromising gene expression and regulation of cell signaling pathways, and modulating force generation, leading to fatigue [5-7]. Physical training can increase the activity of enzymes capable of neutralizing ROS [8]. To increase body stores and avoid the deleterious effects of oxidative stress, many health professionals in the movement area have considered and recommended the use of supplementation with antioxidants to improve health, recovery after exercise, and the balance of oxidative excess [9].

One of the emerging possibilities is supplementation with açai, a fruit found in several regions of South America, with the largest areas found in the Brazilian Amazon, especially in the states of *Amazonas, Amapá*, and *Pará* [10]. Two species of açai are among the most widely consumed (*Euterpe Precatoria* and *Euterpe Oleracea Mart.*), however, *Euterpe Oleracea Mart*. is the most commonly exported in Brazil. Regarding biochemical composition, both açai species are characterized by similar polyphenolic profiles and comparable antioxidant capacities [11]. In recent years, açai has been notable among tropical fruits for its high phytochemical and antioxidant potential and its positive effects on health, as well as its commercial potential [12,13]. It is worth highlighting that the variety of phytochemicals present in açai, such as anthocyanins, flavanones, flavanonols, flavone-C-glycosides, flavones, dehydroflavonols, flavonols, phenolic acids, and procyanidins with antioxidant properties result in better antioxidant capacity as well as cancer-preventive, lipid-lowering, and cardioprotective effects, among others [14-17].

In relation to açai processing, 12% of the production of processed açai in the world is directed towards the production of energy and sports drinks, indicating a positive association between the consumption of açai and the practice of physical exercises, which has been increasingly explored by marketing companies [18].

Although some studies have investigated the effects of açai supplementation linked to exercise, evidence from mapping the topic could identify issues, considerations, and gaps in this body of literature, formulating recommendations for future research. This will help health professionals to better direct their studies, with similar follow-ups and searches, and toward existing disparities in the area, along with ramifications for studies not yet addressed, as well as the implementation of açai supplementation in an appropriate way for athletes, patients, and other individuals who could benefit from consumption.

Initially, a search was carried out in the JBI Database of Systematic Reviews and Implementation Reports, Cochrane Database of Systematic Reviews, CINAHL, PubMed, and PROSPERO for any type of review on açai and exercise, and no studies were identified. Thus, we aimed to map research evidence from primary studies in animals and humans that examined the effects of açai supplementation associated with physical exercise protocols. The intention was to catalog which biochemical, physiological, and performance results were investigated in these studies, as well as to summarize the main methods used in the research field. We chose to conduct a scoping review to synthesize the evidence, since the theme (açai and exercise) presents some novelties, which makes a systematic review unfeasible [19]. In addition to capturing the relevant literature on the topic, regardless of the study design, this could also be used to identify parameters and gaps in the literature [20].

METHODS

Protocol and registration

This is a scoping review with methodological decisions based on the Joanna Briggs Institute Reviewer's Manual, 2015. The report of this review was prepared using the reported items referenced to review the

scope of the extension in the form of a PRISMA search algorithm checklist, and subsequently registered in the Open Science Framework platform with the digital object identifier DOI:10.17605/OSF.IO/VS2WB, which can be accessed through the link <osf.io/mc8d3>.

Eligibility criteria

This review addressed the research question "What are the effects of açai supplementation (*Euterpe Oleracea Mart.*) associated with physical exercise when performed in animals and humans?". The inclusion criteria were established according to the acronym PCC for a scoping review: the participants (animal or human), the concepts (acute or chronic supplementation with açai), and the context (physical exercise). Thus, studies were included: 1) experimental, observational, and descriptive studies, without date or language limitations; 2) those that used animals, regardless of species, as well as those that used humans, regardless of sex, age, or level of physical fitness; and 3) that used the açai *Euterpe Oleracea Mart.*, due to its wide availability and use in the Amazon region, as well as its large number of flavonoids. Studies that used other açai species (*e.g.*, *Euterpe Pecatoria, Euterpe Eudilus*) and review articles were not included.

Selection of Sources of Evidence and Search Strategy

The selection of records was carried out between July and August 2021 and the review in September 2021. For the searches in the databases, supplementary material from a search algorithm was used, which allows for greater efficiency in the search of the researched platforms: (a) Medical Literature Analysis and Retrieval System Online – Medline (PubMed), (b) Scopus, (c) Web of Science, (d) Sport Discus, (e) Embase, and (f) Scielo. The descriptors (MeSH terms) and keywords used were divided into two groups; the first focused on the search for results in açai, with the terms: "Açai", "Anthocyanin", "Euterpe Oleracea Mart.", and "Euterpe" in conjunction with the Boolean operator "OR". The second focused on exercise, with the terms: "Physical Exercise", "Aerobic Exercise", "Training, Exercise", "Exercise", in conjunction with the Boolean operator "OR". Subsequently, the search was performed with both terms and using the Boolean operator "AND" for the joint search of mesh terms. The selected articles went through the PRISMA checklist, and all included articles were read in full. The existence of other relevant records was verified by checking the references of the selected articles.

Data extraction and synthesis

Data extraction took place between June and July 2021 and was performed by two independent authors. The selected articles were read in full and the existence of other relevant records was verified by checking the references of the selected articles. The extracted data were classified into five categories, both for animal and human studies: sample characteristics, intervention with açai, intervention with exercise, variables, and açai plus exercise effects. All data are presented in tables.

RESULTS

A total of 342 articles were found in the databases. After removal of duplicates, and tracking the theme, 18 articles were considered eligible. Finally, the titles and abstracts were read, leading to 11 articles that were included in the research, 5 with animals and 6 with humans (Figure 1).

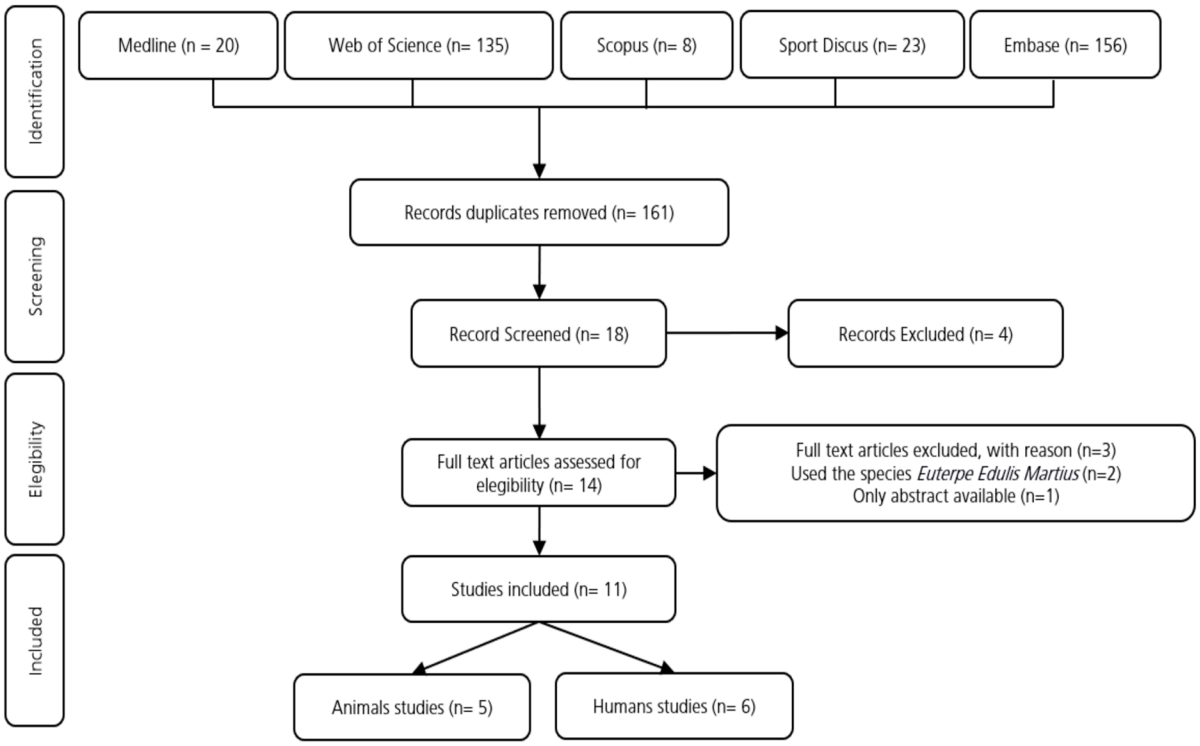

Figure 1 – Flowchart of the study selection procedure.

Characteristics of animal experimental studies

Few studies have evaluated the effects of açai supplementation and exercise in animal models, all of them from Brazil (n=5) and using Wistar rats [21-25]. The included studies involved models with myocardial infarction, diabetes *Mellitus*, and acute and chronic supplementation [21,22-25].

Açai supplementation

A common feature in most of the studies was a 4-week intervention period, except for one study that evaluated 5 weeks and one study that evaluated 8 weeks [21-25]. The investigations by Bem *et al*. [22,23] and Andrade *et al.* [24] applied 200mg / kg of açai seed stratum, and Zapata-Sudo *et al.* [21] and Lovorato *et al.* [25] used 100 mg / kg daily.

Intervention with exercise

Treadmill running was implemented in all studies involving animal models. However, while Zapata-Sudo *et al.* [21] performed one intervention with running at progressive intensities, Bem *et al.* [22-23] used protocols at an intensity between 50 and 60% of the maximum speed. De Andrade Soares *et al.* [24] utilized an intensity between 50 and 60% of the maximum speed during the training and 5 maximal stress tests (pre, 2nd, 3rd, 4th, and 5th weeks). Lavorato *et al.* [25] included protocols at an intensity between 60 and 70% of the maximum speed.

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Investigated variables

Considering that the studies included models of myocardial infarction and diabetes *Mellitus*, the main variables analyzed were hemodynamics, related to glucose and hepatic metabolism. In addition, oxidative stress, lipid profile, vascular function, mitochondrial biogenesis, and performance markers were also assessed.

Positive effects of açai associated with exercise in an animal model

Although the study by Zapata-Sudo *et al.* [21], used only treadmill running to investigate the effects of açai supplementation, the results indicated that infarcted rats supplemented with açai showed improvements in exercise tolerance and several hemodynamic parameters. On the other hand, in diabetic rats [22-23], açai supplementation associated with running training led to significant improvements in liver markers [22] and glucose metabolism [23]. De Andrade Soares *et al.* [24] reported that chronic ASE supplementation improves aerobic physical performance, by increasing vascular function, reducing oxidative stress, and positively regulating the key proteins of mitochondrial biogenesis (Table 1).

Table 1 – Studies in animals that consumed açaí (*Euterpe oleracea Mart.*) and performed exercise protocols.

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Author	Sample characteristics	Intervention (Açai)	Intervention (Exercise)	Variables	Açai+Exercise effects
Zapata-Sudo, *et al.* [1]	18 Wistar rats Control group n=6 Myocardial Infarction group=12 n=6 with açai supplementation, n=6 without açai supplementation	100 mg/kg/day açai seed extract, for 4 weeks.	Treadmill run until fatigue (8m/min, 12m/min, 18m/min with 3 min each step)	Performance total running distance Hemodynamic parameters SAP, DAP, left ventricular systolic pressure, left ventricular diastolic pressure, relaxation rate, cardiac hypertrophy Other rat weight, collagen volume of the left ventricle	Performance ↓exercise intolerance Hemodynamic parameters ↑SAP, ↑Left ventricular systolic pressure, ↓Left ventricular diastolic pressure, ↓cardiac hypertrophy Other ↓ Collagen Volume Fraction
de Bem, *et al.* [2]	40 diabetic rats n=10 rats (açai+exercise) n=10 rats (exercise) n=10 rats (açai+sedentary) n=10 rats (sedentary) 40 Control rats n=10 rats (açai+exercise) n=10 rats (exercise) n=10 rats (açai+sedentary) n=10 rats (sedentary)	200 mg /kg/day of acai seed extract for 4 weeks	Treadmill running (30 min/day; 5 day/week, during 4 weeks at 50 to 60% of the maximal velocity)	Serum assays TC, HDL, LDL, VLDL, TG, AST, ALT Western blotting LKB1, PLKB1, AMPK, pAMPK, SREBP-1C, ACC, pACC, MTP, ABCG5, ABCG8, HMGCo-A Others SOD, CAT, GPx, glycogen, liver weight, steatosis, carbonyl(plasma), carbony (liver), MDA(plasma), MDA(liver), 8-Isoprostane	Western Blotting ↓GL final, ↓MTP, ↓HMGCoA-R, ↑ABCG8, Other ↓liver weight, ↓steatosis, ↓carbonyl (plasma) ↓MDA (plasma), ↓% 8-isoprostane, ↑SOD (liver), ↑GPx (liver)

Table 1 – Studies in animals that consumed açaí (*Euterpe oleracea Mart.*) and performed exercise protocols.

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Author	Sample characteristics	Intervention (Açai)	Intervention (Exercise)	Variables	Açai+Exercise effects
de Bem, *et al.* [3]	40 diabetic rats n=10 rats (açai+exercise) n=10 rats (exercise) n=10 rats (açai+sedentary) n=10 rats (sedentary) 40 Control rats n=10 rats (açai+exercise) n=10 rats (exercise) n=10 rats (açai+sedentary) n=10 rats (sedentary)	GA: 200mg / kg / day açai seed extract. For 4 weeks. GC: nothing	Treadmill running (30 min /day; 5 day/ week, during 4 weeks at 50 to 60% of the maximal velocity)	Lipid profile TC, VLDL, HDL, LDL, TG, HbA1c Western Blotting IR, AKT, pAKT, GLUT-4, pAMPK Serum Assays IL-6, TNFα, GLP-1, Leptin Other Insulin, HOMA-IR, HOMA-B	Diabetic group ↓HbA1C, ↓Insulin, ↓Homa-IR, ↓IR, ↑pAKT, ↑Adiponectin
Soares, *et al*. [4]	81 Wistar rats n=17 sedentary n=14 sedentary + chronic ASE n=18 training n=17 training + chronic ASE n=15 training + acute ASE	200mg/kg/day for 5 weeks Training+ASE acute=30 min before test	Treadmill running until fatigue (3m/ min, increasing 4m/ min every 3 min until exhaustion)	Performance total running distance time Western blotting p-eNOS, MDA, SOD, GPX, Catalase, NO2, PAMPK/AMPK, SIRT-1, Nrf-2, PGC1α Other Weight, glucose, lactate.	Performance total running distance: ↑training+chronic ASE time: ↑training+chronic ASE Western blotting Training+acute ASE ↑p-eNOS, ↑MDA Training+chronic ASE ↑SOD, ↑GPX, ↑Catalase, ↑NO2, ↑P-AMPK/AMPK, ↑SIRT-1, ↑Nrf-2, ↑PGC1α
Lavorato, *et al.* [5]	50 rats n=10 rats (Control) n=10 rats (High-fat Diet) n=10 rats (High-fat Diet + Açai) n=10 rats (High-fat Diet + AET) n=10 rats (High-fat Diet + Açai + AET)	GA: 100mg/kg/day açai seed extract, for 4 weeks. GC: nothing	Treadmill running until fatigue (5 times/week, 60 min/day, 60-70% of maximum running speed (MRS), for 8 weeks)	Performance total running distance time Body composition and running capacity IBM, FBM, BMG, BW, HW, VW, LVW, Initial TTF, Final TTF Western blotting mRNA, MDA, CP, SOD, Catalase, GTS.	Performance total running distance: ↑TTF+HAT Body composition and running capacity ↑BGM ↑FinalTTF Western blotting Training+chronic ASE ↓MDA, ↓CP, ↑Catalase, ↑GTS

Note: ABCG5: ATP Binding Cassette Subfamily G Member 5; ABCG8: ATP Binding Cassette Subfamily G Member 8; ACC: Acetyl CoA Carboxylase; AET: Aerobic Exercise Training; AKT: Protein Kinase b; ALT: Alanine Aminotransferase; AMPK: Adenosine Monophosphate Activated protein kinase; Anti-GLP-1: Anti-leptin and Glucagon-like Peptide-1; Anti-IL-6: Anti-Interleukin 6; Anti-TNF-alfa: Anti-Tumor Necrosis Factor Alpha; AST: Aspartate Aminotransferase; BMG: Body Mass Gain; BW; Body Weight; CAT: Catalase; CP: Carbonyl Protein; DAP: Diastolic Arterial Pressure; EH: Hepatic Steatosis; FBM: Final Body Mass; GA: Group Açaí; GC: Group Control; GLP-1: Leptin and Glucagon-like Peptide-1; GLUT-4: Glucose Transporter 4; HAT: High-Fat Diet + Açai + AET; HbA1c: Glycosylated Hemoglobin; HDL: High-Density Lipoprotein; HMGCo-A: 3-Hidroxi-3-Methyl-Glutaril-CoA Redutase; HOMA-B: Homeostasis Model Assessment - B cell ; HOMA-IR: Homeostasis Model Assessment - Insulin Resistance; HPLC: High- Performance Liquid Chromatography; HW: Heart Weight; IBM, Initial Body Mass; IL-6: Interleukin 6; IR: Insulin Receptor; LDL: Low-Density Lipoprotein; LKB1: Liver Kinase B1; LVW: Left Ventricular Weight; MAB: Mesenteric Arterial Bed; MALDI-TOF: Matrix Assisted Laser Desorption Ionization Time of Flight Mass Spectrometry; MDA: Malondialdehyde; MTP: Microsomal Triglyceride Transfer Protein; nNOS: Neuronal Nitric Oxide Synthase; pACC: Phosphorylated Acetyl CoA Carboxylase; pAKT: Phosphorylated Protein Kinase b; pAMPK: Phosphorylated Adenosine Monophosphate Activated Protein Kinase; p-eNOS: Phosphorylated Endothelium Nitric Oxide Synthase; PGC1α: Peroxisome Poliferator-Activated Receptor Gamma Coactivator; pLKB1: Phosphorylated Liver Kinase B1; PP: Perfusion Pressure; SAP: Systolic Arterial Pressure; SIRT-1:sirtuin-1; SOD: Superoxide Dismutase; SREBP-1C: Transcription Factor Sterol Regulatory Element Binding Protein-1c; TC: Total Cholesterol; TG: Triglyceride; TNF-alfa: Tumor Necrosis Factor Alpha; TTF: Total Exercise Time Until Fatigue; TTF: Total Exercise Time Until Fatigue; VLDL: Very Low Density Lipoprotein; VW: Ventricular Weight.

Characteristics of human experimental studies

All studies were published from the year 2014 onwards. In the articles with humans, the majority of authors are from Brazil (n=5) [26-30] and only one article is from Poland (n=1). Regarding the characteristics

of the participants, only men were included, aged between 16 and 48 years. In one of the studies analyzed the participants engaged in strength training (bodybuilders), while the other participants performed aerobic predominance activities (runners and cyclists) [31].

Açai supplementation and placebo

Considering the duration for which the participants received açai supplementation, 3 studies carried out acute supplementation, lasting from 3 to 5 days [26-28], while the other studies included a longer supplementation period, ranging from 15 to 42 days [29-31]. The amount of açai ingested daily varied from 100 ml [31] to 300 ml [26] of juice. In addition to juice, açai was ingested as a gel (90 g / day) [28] or a pulp (dehydrated powder) in quantities of 5 g / day [27], 200 g / day [29], and 400 g / day [30]. Only 50% of the studies employed a placebo. Carvalho-Peixoto *et al.* [26] used 300 ml of yellow fruit juice / day for 3 days, Fantini *et al.* [27] implemented powdered sugar capsules, and [29] supplemented with non-red fruits.

Intervention with exercise

From the 6 studies analyzed, 3 performed interventions with exercise lasting more than 15 days, [29-31] and the others included only 2 interventions (Control and Placebo). Running was the most commonly applied form of training and evaluation [26,27,29,31], followed by maximum strength tests [27-28] and cycling [30].

Investigated variables

Performance indicators were considered in most of the included studies [26-31], however, with a wide variety of methods, such as time to complete 10 km [29], exhaustion time of 90% VO_{2max}, [26], time in agility tests, vertical displacement [27], maximum power on a cycle ergometer, heart rate, and individual anaerobic threshold [30]. Creatine Kinase (CK) and Lactate Dehydrogenase (LDH) were the main markers of muscle damage. Furthermore, markers of oxidative stress, antioxidant activities [26,28,30,31], and inflammation [27,30] were considered, as well as blood count [26,28,30] and subjective parameters of effort intensity, such as Rating of Perceived Effort (RPE) [26,29,30].

Positive effects of açai associated with exercise in humans

Açai supplementation demonstrated positive results in increasing exhaustion time to 90% VO_{2max} and heightened intensity at the anaerobic threshold [26,30]. Exciting outcomes have also been found in muscle damage markers, where significant reductions in post-exercise CK and LDH were reported [28-29]. A reduction in the lipid profile was observed [31], as well as in lymphocytes, both at rest and after exercise [26] and leukocytes [28]. Increased activity of the antioxidant marker Glutathione Reductase (GR) was also noted [31], along with Trolox Equivalent Antioxidant Capacity (TEAC) [30] and Glutathione Peroxidase (GP) reduction [28]. On the other hand, decreased oxidative stress markers such as Malondialdehyde (MDA) were reported [26,30]. Regarding lactate production, lower levels [la] were detected in submaximal intensities [30] and during the recovery process [31]. Finally, it seems that açai supplementation is able to reduce central and peripheral RPE [26] (Table 2).

Table 2 – Studies in humans that consumed açaí (*Euterpe oleracea Mart.*) and performed exercise protocols.

1 of 2

Author	Sample characteristics	Intervention (Açai)	Intervention (Exercise)	Variables	Açai + Exercise effects
Sadowska- -Krępa, *et al.* [6]	7 men, obstacle jumpers. (Age: 16 to 18 years)	GA: 100ml Juice açai/day. For 42 days (6 weeks). GC: nothing	Sprint test of 300m (Begin)+6 to 7 training sessions/ week, with 90 min each session+Sprint test of 300m (End)	Muscle damage markers CK, LDH Antioxidant Markers SOD, GSH-Px, CAT GR Non-enzymatic activity GSH, Uric Acid, Total plasma polyphenols, TBARS Hemogram Total Cholesterol, HDL, LDL, TG, Total cholesterol/HDL, LDL/ HDL, TG/HDL, AIP Other [La]	Antioxidant Markers ↑ GR after 1h recovery Non-enzymatic activity ↑GSH Pre-exercise ↑ Total Plasma Polyphenols Pre-exercise Hemogram ↓Total Cholesterol pre-exercise and after 1hr recovery ↓LDL pre-exercise and after 1h recovery ↓LDL/HDL pre-exercise Other ↓[La] post-exercise
Carvalho- -Peixoto, *et al.* [7]	14 pentathletes (7 Açai group and 7 Control group). (Age: 20 to 32 years)	GA: 300 ml of acai juice / day. For 3 days. GC: 300ml of yellow fruit juice / day for 3 days.	VO2max test (treadmill) + 5min to 60% VO2max Time to exhaustion at 90% VO2max	Performance Time to exhaustion at 90% VO2máx Muscle damage markers LDH, CK Hemogram Total Leukocytes, Lynphocytes, Semented cells, Ammonia, Urate, Urea, Creatinine, ALT, AST Oxidative stress marker MDA Antioxidant marker GPx Others C-RPE, L-RPE	Performance ↑Time to exhaustion at 90% VO2máx Muscle damage markers ↑LDH Hemogram Baseline ↓Lymphocytes, ↓Creatinine Post-Exercise to Exaustion ↓Lynphocytes, ↓Ammonia, ↑ Urea, ↓Creatina Oxidative stress marker ↓MDA Others ↓C-RPE during all time exhaustion test, ↓L-RPE 4th of time exhaustion test
Fantini, *et al.* [8]	Study 01: Açai Group=10 men Placebo Group= 10 men Age= 21years Study 02 Açai Group=10 men Placebo Group= 10 men Age= 21years	Study 01: 4 capsules with 1g açai extract per capsule. 2 capsules before protocol and 2 capsules after protocol. Study 02: 4 capsules with 1g açai extract per capsule. 2 capsules before protocol and 2 capsules after protocol	Study 01: 1RM leg press + VO2max test + Downhill Running (15min) + T test (agility). Study 02: 1RM leg press + VO2max test + Downhill Running (15min)+T test (agility)	Study 01 Performance Agility performance, Vertical displacement Muscle damage markers Muscle soreness (Gastrocnemius, Hamstring, Quadriceps), Range of motion (Knee and Hip). Study 02 Muscle damage marker CK Inflammation marker CRP	Study 01 Muscle damage markers ↓ Muscle soreness in hamstrings and quadriceps 24h and 48h after downhill running. Study 02 No effects
Viana, *et al.* [9]	17 Bodybuilders. (Age: 21 to 42 years)	GA: 90 g sachet (2x 45g)/day per 3 days. GC: nothing	Warm Up (2 set of 15 reps)+1RM test	Hemogram Leucocytes, Lymphocytes, Ammonia, TG, TGP, Uric Acid, Creatinine	Hemogram ↓Leukocyte, ↓TGP Muscle damage markers ↓CK, ↓LDH Antioxidant Markers

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Table 2 – Studies in humans that consumed açaí (*Euterpe oleracea Mart.*) and performed exercise protocols.

Author	Sample characteristics	Intervention (Açai)	Intervention (Exercise)	Variables	Açai + Exercise effects
Viana, *et al.* [9]				Muscle damage markers CK, LDH Oxidative stress markers MDA Antioxidant Marker GPx	↓GPx
Cruz, *et al.* [10]	14 runners (8 men açai Group) (6 men control Group) (Age: 24 to 48 years)	GA: 200 g pulp/ day (2x de 100g) for 25 days. GC: No red fruits	10 km running test (Begin) Week 1= 26 km (4x/ week) Week 2= 32 km (4x/ week) Week 3= 28km (4x/ week) 10 km running test (End)	Performance Time to 10km Muscle damage markers CK Others RPE, caloric intake, anthropometry	Muscle damage markers ↓CK 24h after 10 km running test
Terrazas, *et al.* [11]	10 cyclists (5 men açai Group) (5 men control Group) (Age: 24 to 48 years)	GA: 400g pulp/day for 15 days. GC: 400g placebo/ day for 15 days.	Incremental Test: bicycle starting at 150W+25W every 2 minutes until exhaustion.	Performance Wmax, HRT, ATi Antioxidant marker TEAC Oxidative stress markers MDA Anti-inflammatory markers IL-6, TNF-alfa Others Lactate, RPET	Performance ↑ATi Antioxidant marker ↑TEAC Oxidative stress marker ↓ MDA Other ↓Lactate to 300W

Note: AIP: Acute Intermittent Porphyria; ALT: Alanine Aminotransferase; AST: Aspartate Aminotransferase; ATi: Anaerobic Threshold Intensity; CAT: Catalase; CK: Creatine Kinase; CRP: C-Reactive Protein; C-RPE: Central Rating of Perceived Exertion; DM: Muscle Damage; DMT: Late Muscle Pain; GA: Group Açaí; GC: Group Control; GPT: Glutamic-Pyruvate-Transaminase; GPT: Glutamic-Pyruvic Transaminase; GPx: Glutathione Peroxidase; GR: Glutathione Reductase; GSH: Glutathione; GSH-Px: Glutathione Peroxidase; HDL: High Density Lipoproteins; HLH: Hemophagocytic Lymph Histiocytosis; HRT: Heart Rate Threshold; IL-6: Interleukin 6; LA: Long and Accurate; LDH: Lactate Dehydrogenase; L-RPE: Local Rating of Perceived Exertion; MDA: Malondialdehyde; RM: Maximum Repetition; RPET: Rating of Perceived Exertion Threshold; SOD: Superoxide Dismutase; SPE: Subjective Perception of Effort; TBARS: Thiobarbituric Acid Reactive Substances; TEAC: Trolox Equivalent Antioxidant Capacity; TG: Transglutaminase; TNF-alpha: Tumor Necrosis Factor Alpha; VO2max: Maximum oxygen volume uptake; W: Watts; Wmax: Maximum Workload Reached.

DISCUSSION

The current review aimed to summarize studies on the physiological, biochemical, and performance effects caused by açai supplementation associated with physical exercise. To the best of our knowledge, this is the first review of studies that present this body of evidence. According to Bezerra *et al.* [18], açai is an important socioeconomic factor for the Amazon region. Besides being part of the food culture of this region, açai is also exported in the form of frozen pulp and dyes, and has been used by the pharmaceutical, cosmetic, and food industries. Moreover, according to the authors, in 2012 the national fruit production reached 817.2 thousand tons and was valued at US $ 1.2 billion, with great potential for expansion. In the European market, açai has great commercial possibilities, especially because it is associated with natural, healthy, and nutritious fruit juices, in addition to its tropical origin, and the existence of well-established national markets and processing industries [13].

Concerning the characteristics of açai supplementation, in the reviewed studies involving animals, the amounts used were 100 and 200 mg / kg / day of seed stratum. This seed stratum application is a strategy that has been widely used by other authors [32-37]. In a smaller amount, the use of pulp is observed [8-38].

In human studies, on the other hand, the amount and form varied from 100 to 300 ml of juice, 90 g / day of gel, or up to 400 g / day of dehydrated food. In the literature, in studies that used açai supplementation, without associating it with exercise, the use of 200 g / day of pulp has been widely implemented [16-39], and recently, the juice (650 ml / day) has also been applied [40].

In animals, one of the included studies found that supplementation with açai associated with exercise changed several cardiovascular and hemodynamic indicators [21]. The mechanisms to explain this included the suggestion that polyphenol present in açai seeds increases the production of endothelial Nitric Oxide (NO), leading to relaxation of the endothelium [35]. In addition, açai is associated with the reduction in reactive oxygen species, regulating lipid metabolism in different pathological conditions. Although none of the human studies included in our review assessed the effects of açai supplementation on cardiovascular and hemodynamic parameters, one study reported the benefits of açai supplementation for vascular function [17]. According to the authors, significant increases of 1.4% after 2h and 0.8% after 6h in flow-mediated brachial artery dilation were reported. Conversely, studies that supplemented with açai and monitored the blood pressure response did not report significant changes [16,17,39].

De Bem *et al.* [23] employed an animal model and reported significant improvements in markers related to glucose homeostasis when açai supplementation was associated with physical exercise. The authors suggest that the association between açai and exercise may involve the reduction in hyperinsulinemia, activation of insulin signaling in muscle and fat tissue, and elevation of Leptin and Glucagon-like Peptide-1 (GLP-1) levels and anti-inflammatory capacity, contributing to the improvement in insulin sensitivity. Even though açai consumption is recommended as a complementary therapeutic strategy for diabetes treatment, to the best of our knowledge, no human studies have been developed associating its ingestion with glucose homeostasis markers in diabetics [41,42].

Another study included in our review, evaluated the liver function of diabetic rats [22]. According to the authors, the positive results observed were due to the Adenosine Monophosphate Activated protein kinase (AMPK) mediated decrease in hepatic lipogenesis, inhibition of Very Low Density Lipoprotein (VLDL) and Triglycerides (TG) assembly, and secretion via the Microsomal Triglyceride Transfer Protein (MTP) pathway. In addition, there was increased excretion of cholesterol in bile by the ATP Binding Cassette Subfamily G Member 8 (ABCG8) transporter and the antioxidant property that contributes to reduced lipids and improved liver metabolism. Reduction in hepatic steatosis in rats supplemented with açai was also reported by [12]. The authors state that açai supplementation increases adiponectin levels, insulin sensitivity, and Peroxissome Proliferator-Activated Receptor Alpha (PPAR-α) -mediated fatty acid oxidation. The combination of these factors reduces the accumulation of fats in the liver. No studies were found that have evaluated the effects of açai supplementation on liver function in humans.

Our review indicated that the association between açai supplementation and exercise was able to increase antioxidant capacity [22,28,30,31], reduce oxidative stress [23,26], and decrease muscle damage markers [26,28-30], indicating a lower inflammatory response. According to Neri-Numa *et al.* [15], açai is composed of large amounts of antioxidants, such as anthocyanins, proanthocyanidins, flavonoids, phenolic acids, and resveratrol, which would be responsible for these responses. In addition, a great deal of research has investigated the effects of açai on antioxidant, anti-inflammatory, and oxidative stress, both in animal models and human models [43-45,39].

FINAL CONSIDERATIONS

This scoping review provided an overview of the effects of açai supplementation associated with exercise in humans and animals. As far as we know, this is the first study with this objective. We understand

that the low number of articles related to the theme is a limitation for the development of a systematic review, which reinforces the importance of the synthesis of evidence through a scoping review.

Based on previous results and to support further research on the subject, future guidelines can be considered for animal studies: (a) açai supplementation and exercise in obese models to test the effect of adiponectin on body composition, and (b) analysis of histological and histochemical parameters caused by the association of açai supplementation and exercise. For studies in humans, research recommendations include (a) investigation of the effects of açai supplementation on eccentric injury protocols, with the incorporation of muscle quality variables to assess recovery; (b) chronic açai supplementation and strength training in relation to physical performance markers; and (c) comparison of different forms of açai supplementation in exercise protocols. We believe this is associated with using healthy people and we encourage the development of future studies associating açai supplementation with a hypertensive public to confirm or refute the effects on blood pressure response.

In conclusion, in studies with animals, where pathological models can be better controlled, supplementation with açai and exercise has shown encouraging results in the improvement in hemodynamic and hepatic parameters of glucose metabolism and performance. In humans, previous results indicate positive effects on increased performance and antioxidant activity as well as a reduction in muscle damage markers, inflammation, and perceived exertion. However, the wide variety of methodologies employed (quantity and form of supplementation, exercise modalities, previous experience, and duration of interventions) are still barriers to better understanding of the phenomena involved.

There are several applications for açai supplementation both for athletes and normal individuals who seek greater physical performance in specific practices, as well as for those aiming to improve the regenerative process. Future research that addresses the recommendations from this review are encouraged as they will help practitioners decide how to include açai supplementation during exercise programs, due to the various anti-inflammatory and antioxidant factors already addressed in the current study, which indicate the benefits of supplementation, without presenting contraindications for the use of açai in moderation and with adequate monitoring.

CONTRIBUTORS

TMP DOS REIS, GG AGUIAR and M ROSSATO participated in the conception, design, execution, writing, and revision of the study. V BARBOSA-FILHO and ES LIMA contributed to the writing and revision of the study.

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