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Craving, cognition, and self-esteem in adults with crack cocaine use disorder participating in inpatient multicomponent exercise: a prospective naturalistic study

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Craving, cognition, and self-esteem in adults with crack cocaine use disorder participating in inpatient multicomponent exercise: a prospective naturalistic study

Running head: Exercise and Craving in Crack Cocaine Use Disorder

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Abstract

Objective: To investigate whether participation in a multicomponent physical exercise program is associated with longitudinal changes in craving, cognition, and self-esteem among inpatients with crack cocaine use disorder.

Methods: This prospective, naturalistic, non-randomized longitudinal study included 37 inpatients with crack cocaine use disorder classified into an exercise group (EG, *n* = 21) or non-exercise group (NEG, *n* = 16) based on participation in the institutional exercise program. Assessments were conducted at baseline, week 5, and week 10. Outcomes included global cognition (MMSE), executive function (TMT-A/B), self-esteem (RSE), and craving (CCQ-Brief). Longitudinal data were analyzed using repeated-measures models.

Results: No significant group-by-time interactions were observed for cognition or self-esteem, although both groups improved over time. In the primary analysis, a significant group-by-time interaction was observed for craving ($p = 0.034$), with greater reductions

in the exercise group, particularly during the first five weeks. However, this interaction was attenuated after adjustment for age and duration of crack cocaine use.

Conclusion: Participation in multicomponent exercise was associated with greater reductions in craving in the primary analysis, although this finding was attenuated after adjustment for baseline group differences. Improvements in cognition and self-esteem were observed in both groups, suggesting shared effects of structured care and abstinence. These findings support further investigation of exercise as a complementary strategy in substance use disorder treatment.

Keywords: Cocaine-Related Disorders; Craving; Exercise; Inpatients; Executive Function; Self-Esteem.

Introduction

Cocaine use remains a major global public health concern, with an estimated 22 million users worldwide in 2021, representing a 23% increase over the past decade.[1] Although most epidemiological data focus on powdered cocaine, crack cocaine remains a particularly concerning form due to its clinical severity and substantial public health burden. In Brazil, national data indicate that crack cocaine use persists as a significant issue. Although prevalence rates have remained relatively stable (approximately 1.4% lifetime and 0.5% in the past year), perceived availability is high, with nearly half of the population reporting easy access to the substance.[2]

Unlike powdered cocaine, crack cocaine is typically smoked, allowing rapid pulmonary absorption and a sharp increase in dopaminergic activity, resulting in an intense but short-lived euphoric effect that reinforces repeated use.[3] Over time, repeated exposure leads to neuroadaptations in reward-related pathways, strengthening compulsive drug-seeking behavior and increasing the severity of dependence. In addition to its addictive potential, chronic crack cocaine use has been associated with cognitive impairment, reduced self-esteem, and elevated craving—an intense urge to use the substance often triggered by environmental cues or negative emotional states.[4] These clinical features are particularly relevant in treatment settings, as they may directly interfere with treatment engagement, adherence, and relapse prevention.

In this context, physical exercise has emerged as a potential adjunctive strategy in the treatment of substance use disorders, offering physiological and psychological benefits that may support recovery.[5] However, most studies have focused on single-

modality interventions, such as aerobic training or strength training, which may not fully address the multifaceted impairments associated with addiction.[6] Aerobic training has been associated with improvements in memory and learning,[7] whereas strength training has been linked to enhancements in motor control and executive function.[8] Because these modalities may engage partially distinct mechanisms, their isolated effects may be limited, suggesting that more integrative approaches could promote broader and more consistent benefits.[9]

Multicomponent physical exercise has been proposed as a more comprehensive strategy because it can simultaneously target different physical capacities, including cardiorespiratory fitness, muscle strength, balance, coordination, and flexibility.[10] This approach may promote improvements in cognitive function, self-esteem, and craving regulation, outcomes that are particularly relevant in individuals with substance use disorders.[11] Preliminary evidence supports this perspective. Acute multicomponent exercise sessions have been associated with reductions in craving and improvements in cognitive performance and self-esteem,[12,13] while combined aerobic and strength training has shown greater reductions in craving compared with aerobic training alone.[14] However, these studies are limited by short-term designs, heterogeneous samples, and a lack of specific focus on individuals with crack cocaine use disorder.

Despite these findings, robust longitudinal evidence in individuals with crack cocaine use disorder remains limited. In particular, the potential associations of multicomponent exercise with craving, cognition, and self-esteem in this population are not well established. Therefore, the present study aimed to investigate whether participation in a multicomponent physical exercise program is associated with longitudinal changes in craving, cognition, and self-esteem among individuals with crack cocaine use disorder during inpatient treatment. We hypothesized that participants engaged in the exercise program would show greater reductions in craving and improvements in cognitive function and self-esteem over time.

Methods

Study Design and Setting

This was a prospective, naturalistic, non-randomized longitudinal study conducted at an inpatient philanthropic mental health institution for adults (details blinded for review), where a multicomponent physical exercise program was routinely

offered as part of inpatient therapeutic care. The study was conducted in accordance with the STROBE guidelines for observational studies.

Group allocation was not controlled by the investigators and emerged from routine clinical practice according to participation in the exercise program during hospitalization, which depended on clinical indication and adaptation to the institutional routine. Participants were categorized as exercise group (EG) or non-exercise group (NEG). Both groups received usual multidisciplinary inpatient care, including psychiatry, psychology, nursing, and structured daily routines.

Potential sources of bias included non-random allocation, baseline differences, and attrition during follow-up. These factors were considered in the interpretation of the findings, and baseline adjustment procedures were applied where appropriate. The study was approved by the relevant research ethics committee (details blinded for review), and all participants provided written informed consent prior to participation.

Participants

Clinical records were screened to identify inpatients diagnosed by the institution's psychiatrist with severe cocaine use disorder according to DSM-5 criteria,15 with crack cocaine as the primary form of use. Eligible participants were adult men who had been abstinent for no longer than 72 hours at baseline and had a documented history of physical inactivity for at least one year. Participants were consecutively enrolled upon admission and remained under standard inpatient treatment throughout the observation period. Participant flow is presented in Figure 1.

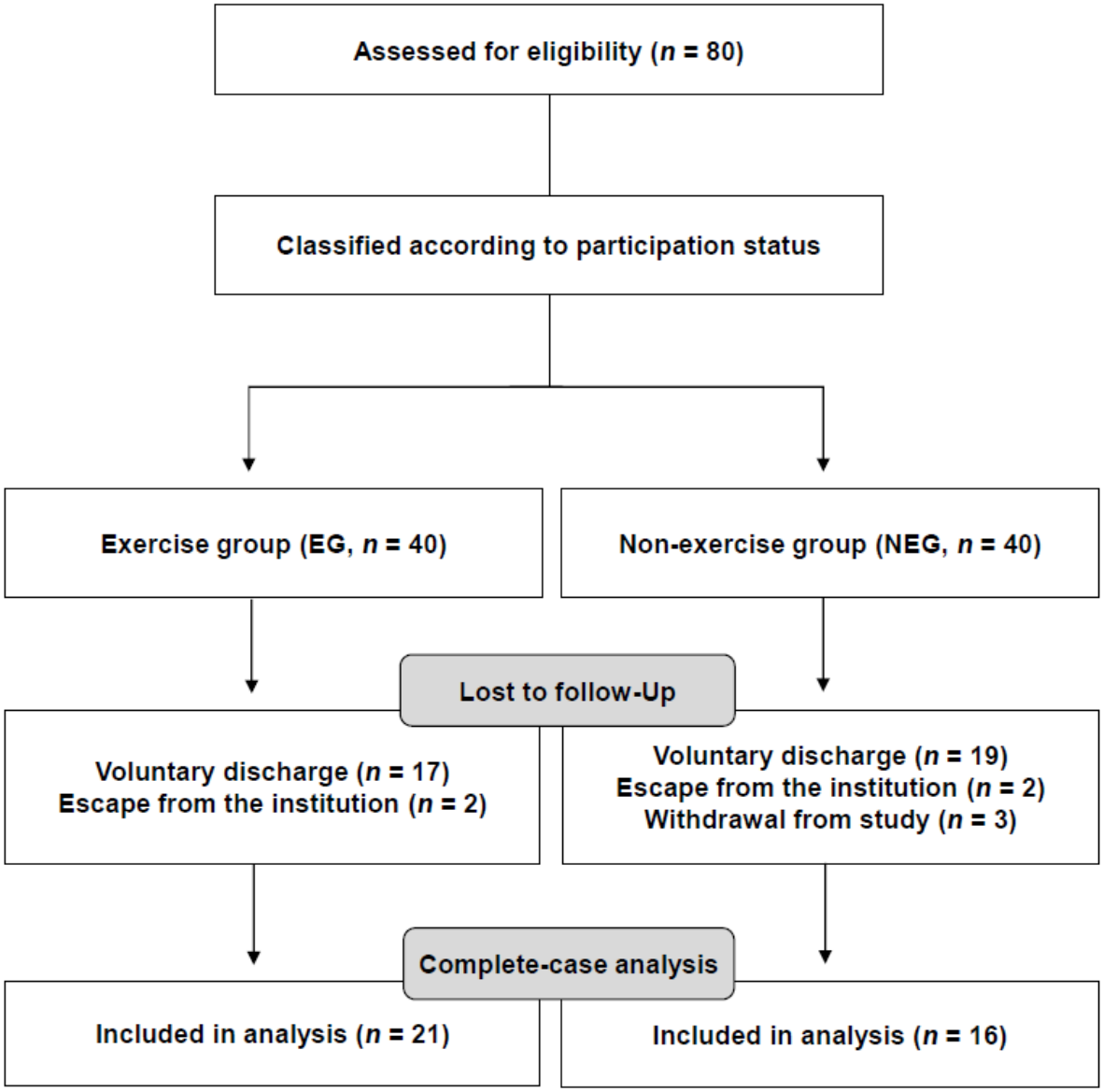

Figure 1 -

Study Procedures and Outcome Measures

Outcome assessments were conducted at three predefined time points: baseline (week 0), mid-follow-up (week 5), and end of follow-up (week 10), using the same schedule for both groups. This design allowed the evaluation of longitudinal trajectories according to participation in the institutional exercise program.

Global cognitive status was assessed using the Mini-Mental State Examination (MMSE).[16] Executive function was evaluated using the Trail Making Test (TMT), including Part A, which assesses processing speed and visual scanning, and Part B,

which assesses cognitive flexibility and set shifting, with performance recorded as completion time in seconds.[17] Self-esteem was assessed using the Rosenberg Self-Esteem Scale (RSE),[18] and craving was measured using the Cocaine Craving Questionnaire–Brief (CCQ-Brief), adapted for hospitalized individuals with crack cocaine use disorder.[19] Brazilian Portuguese versions of these instruments have demonstrated validity, reliability, or normative applicability.[17,20–22] However, formal responsiveness indices for all measures in adults hospitalized for crack cocaine use disorder remain limited.

Exercise Program and Routine Activities

Participants in the EG engaged in the institution's routine multicomponent physical exercise program, performed six times per week, in sessions lasting up to approximately 60 minutes. Session duration included preparation, warm-up, the main exercise activity, recovery intervals, transitions, and cool-down, depending on the daily modality. The program combined aerobic interval training, circuit-based strength training, aquatic activities, and team sports, targeting multiple physical capacities, including cardiorespiratory fitness, muscle strength, balance, coordination, and flexibility. Exercise intensity and progression were monitored using a 1–10 rating of perceived exertion scale.[10] The weekly structure of the main exercise modalities is presented in Table 1.

Participants in the NEG did not participate in the exercise sessions during the observation period but remained engaged in usual inpatient care, including structured therapeutic and recreational activities such as board games, guided reading, videos, and therapist-led group discussions.[23] These activities were performed during a similar institutional time period and were part of standard care, not intended as a comparator condition. Adverse events were monitored throughout the follow-up period, and no serious exercise-related adverse events were reported.

Table 1 - Weekly structure of the multicomponent physical exercise program (EG).

Modality	Days	Sets	Volume	RPE	Recovery
Aerobic Interval Training	Mon, Fri	4	60 s / 90 s	3–5 / 6–8	120 s / 180 s
Strength Training	Tue, Thu	4	8–12 reps	3–5 / 6–8	120 s / 180 s

Aquatic Exercises	Wednesday	–	5 min/exercise	2–3 / 3–5	Continuous
Soccer / Volleyball	Saturday	–	45 min / 3 x 15 pts	Self-selected	–

RPE = rating of perceived exertion (1–10 scale); s = seconds; reps = repetitions; pts = points. Exercise intensity (RPE), volume, and recovery were progressively adjusted throughout the intervention, with lower intensities in weeks 1–5 and higher intensities in weeks 6–10. Mon = Monday; Tue = Tuesday; Thu = Thursday; Fri = Friday.

Statistical Analysis

Descriptive statistics are presented as mean ± standard deviation for continuous variables and as absolute and relative frequencies for categorical variables. Normality and homogeneity of variances were assessed using the Shapiro–Wilk and Levene tests, respectively. Baseline comparisons between groups were performed using independent samples t-tests, Mann–Whitney U tests, or Fisher's exact test, as appropriate. Longitudinal changes were examined using repeated-measures ANOVA for MMSE, RSE, and CCQ-Brief scores and ANCOVA models for TMT-A and TMT-B, including baseline values as covariates. Longitudinal analyses were conducted using complete-case data; missing data were not imputed, and participants who did not complete the final assessment were excluded from the longitudinal models. In response to baseline differences between groups, sensitivity analyses were conducted adjusting for age and duration of crack cocaine use.

For MMSE, RSE, and CCQ-Brief, adjusted repeated-measures ANCOVA models included group, time, the group-by-time interaction, age, and duration of crack cocaine use. For TMT-A and TMT-B, follow-up values were analyzed with baseline performance, age, and duration of crack cocaine use included as covariates. Group-by-time interactions were interpreted as differences in trajectories rather than causal effects. When appropriate, post hoc comparisons were conducted with Bonferroni adjustment. Effect sizes were reported as partial eta squared (ηp^2) and interpreted as trivial (< 0.01), small (0.01 to < 0.06), medium (0.06 to < 0.14), and large (≥ 0.14).[24] In addition, 95% confidence intervals (95% CI) were reported for estimated marginal means and pairwise comparisons where applicable. Statistical analyses were performed using IBM SPSS Statistics (version 29), with $p < 0.05$.

Results

Baseline demographic, clinical, and substance-use characteristics are presented in Tables 2 and 3. At baseline, the EG and NEG differed in age, duration of crack cocaine use, and performance on TMT-A and TMT-B. No other significant differences were observed across sociodemographic, clinical, or substance-use variables, including MMSE, RSE, and CCQ-Brief scores.

Table 2 - Baseline demographic, clinical, and substance-use characteristics

Variables	EG		NEG		p-value
	Mean	(SD)	Mean	(SD)	
Age	29.83	(7.15)	36.85	(10.52)	0.022
Family income (R$)	3,155.30	(3,543.40)	2,685.50	(1,213.20)	0.676
Years of education	10.00	(2.07)	8.50	(4.22)	0.143
Age at first use	18.04	(4.34)	19.11	(5.10)	0.514
Attempts to quit	5.33	(3.62)	5.82	(4.47)	0.712
Maximum abstinence time (years)	1.97	(3.24)	1.13	(1.23)	0.345
Duration of use of crack cocaine (years)	11.81	(6.34)	17.56	(8.92)	0.030
Psychiatric hospitalizations	2.23	(2.21)	3.54	(2.08)	0.078
Suicide attempts	1.86	(1.00)	2.90	(2.70)	0.348
Amount of crack cocaine (units per day)	10.50	(7.62)	6.15	(3.93)	0.063
BMI (kg/m²)	26.06	(5.41)	25.48	(6.52)	0.736

EG = exercise group; NEG = non-exercise group; SD = standard deviation; BMI = body mass index. Family income is reported in Brazilian reais (R$) per month.

Table 3 - Baseline health behaviors and clinical conditions

Categorical variables	EG		NEG		p-value
	No.	(%)	No.	(%)	
Current smoker	15	(71.43)	12	(75.00)	0.555
Alcohol use	14	(66.67)	9	(56.25)	0.379
Recent substance use in the last 30 days	18	(85.71)	12	(75.00)	0.342
Psychiatric medication use	14	(66.67)	12	(75.00)	0.429

Chronic disease	3	(14.29)	7	(43.75)	0.052
Treatment for chronic disease	2	(9.52)	2	(12.50)	0.587

EG = exercise group; NEG = non-exercise group; No. = absolute frequency; (%) = relative frequency.

Longitudinal changes are presented in Tables 4 and 5. No significant group-by-time interactions were observed for MMSE, TMT-A, or TMT-B. MMSE showed a significant main effect of time, indicating overall improvement across the follow-up period in both groups, whereas no significant time or group effects were observed for TMT-A or TMT-B.

Table 4 - Changes in cognitive performance across the intervention period

Variables	EG	NEG	Effect	*F*	p-value	ηp²
MMSE (score)			**ANOVA**			
Pre	26.11 (1.85)	25.20 (2.64)	Group	4.09	0.051	0.11
Mid	27.32 (2.08)	25.92 (2.24)	Time	10.52	< 0.001	0.23
Post	27.94 (1.42)*	27.13 (2.14)	Interaction	0.27	0.757	0.01
TMT–A (seconds)			**ANCOVA**			
Pre	28.42 (9.73)	40.64 (11.00)	Group	0.15	0.697	< 0.01
Mid	24.11 (9.01)	33.22 (9.57)	Time	0.25	0.623	< 0.01
Post	24.05 (9.78)	32.13 (6.83)	Interaction	0.32	0.573	< 0.01
TMT–B (seconds)			**ANCOVA**			
Pre	65.10 (21.44)	106.00 (34.22)	Group	0.03	0.857	< 0.01
Mid	66.00 (23.36)	89.52 (34.20)	Time	0.04	0.844	< 0.01
Post	57.13 (23.68)	79.09 (30.35)	Interaction	0.056	0.827	0.01

Values are presented as mean (standard deviation). *Indicates within-group differences from baseline (week 0) based on post hoc pairwise comparisons with multiplicity adjustment (p-value < 0.05). MMSE = Mini-Mental State Examination. TMT-A/B = Trail Making Test parts A and B. EG = exercise group; NEG = non-exercise group. ANOVA = analysis of variance; ANCOVA = analysis of covariance.

For self-esteem (RSE), a significant main effect of time was observed, with no significant group or interaction effects, indicating similar improvements across groups. For craving (CCQ-Brief), both a significant main effect of time and a significant group-

by-time interaction were observed, indicating different patterns of change between groups, with a more pronounced reduction in the exercise group. Estimated marginal means indicated a progressive reduction in CCQ-Brief scores in the exercise group, decreasing from 21.1 (95% CI: 15.82–26.41) at baseline to 11.0 (95% CI: 10.14–12.03) at post-intervention, whereas the non-exercise group showed smaller changes over time. In sensitivity analyses adjusted for age and duration of crack cocaine use, the group-by-time interaction for CCQ-Brief was attenuated and was no longer statistically significant ($F = 2.64$, $p = 0.107$, $\eta p^2 = 0.07$). Sensitivity analyses did not change the interpretation of the remaining outcomes.

Table 5 - Changes in self-esteem and craving across the intervention period

Variables	EG	NEG	Effect	*F*	p-value	ηp²
RSE (score)			**ANOVA**			
Pre	28.44 (5.88)	25.82 (4.06)	Group	1.28	0.265	0.04
Mid	32.51 (5.14)*	31.71 (4.64)*	Time	34.69	< 0.001	0.49
Post	34.00 (4.65)*	33.13 (4.11)*	Interaction	0.81	0.447	0.02
CCQ-brief (score)			**ANOVA**			
Pre	21.10 (14.70)	14.22 (5.65)	Group	1.60	0.215	0.04
Mid	12.33 (3.85)*	12.40 (4.35)	Time	9.17	0.001	0.21
Post	11.00 (1.86)*	11.71 (2.63)	Interaction	3.55	0.034	0.09

Values are presented as mean (standard deviation). *Indicates within-group differences from baseline (week 0) based on post hoc pairwise comparisons with multiplicity adjustment (p-value < 0.05). Sensitivity analysis adjusted for age and duration of crack cocaine use is reported in the Results section. RSE = Rosenberg Self-Esteem Scale. CCQ-Brief = Cocaine Craving Questionnaire–Brief. EG = exercise group; NEG = non-exercise group. ANOVA = analysis of variance.

Discussion

To our knowledge, this prospective, naturalistic study is among the first to examine longitudinal changes associated with participation in a multicomponent physical exercise program among adults with crack cocaine use disorder receiving inpatient care. The main finding was a greater reduction in craving in the exercise group, particularly during the first five weeks of treatment. In contrast, cognitive performance and self-esteem improved over time in both groups, without clear

differences between participants who engaged in the exercise program and those who did not.

Although no significant group-by-time interaction was observed for MMSE scores, a main effect of time was detected and should be interpreted cautiously, particularly given the observational design and the potential contribution of abstinence-related recovery during inpatient stabilization. MMSE scores increased in both groups over time, a pattern consistent with Almeida et al.,[25] who reported cognitive improvement after four weeks of abstinence among individuals with crack cocaine use. This finding suggests that early improvements in global cognition may occur during inpatient treatment independent of differential trajectories between groups. In addition, years of education were comparable between groups, which may have contributed to relatively preserved baseline cognitive performance and reduced the likelihood of detecting additional changes associated with exercise participation.[26] Furthermore, when global cognition is relatively preserved, the MMSE—although clinically practical—may lack sensitivity to detect subtle changes over short follow-up periods.

For TMT-A, ANCOVA results indicated that baseline performance accounted for a substantial proportion of variance in follow-up outcomes ($\eta p^2 = 0.59$), suggesting that initial scores strongly influenced observed changes over time and limited the ability to detect differential longitudinal patterns. Although mean completion times were numerically lower at follow-up in both groups, these descriptive changes should not be interpreted as evidence of differential improvement in the absence of a significant group-by-time interaction. Thaiyanto et al.[27] reported a significant reduction in TMT-A performance following multicomponent exercise, accompanied by a significant interaction; however, their sample presented substantially poorer baseline performance, indicating a greater margin for improvement. In contrast, baseline TMT-A performance in the present study was consistent with normative values for healthy adults,[28] suggesting relatively preserved attentional processing and the possibility of a ceiling effect limiting detectable changes. This contrast indicates that baseline cognitive status, age, duration of crack cocaine use, and follow-up conditions may partially explain differences across studies.

A similar pattern was observed for TMT-B, for which baseline performance also accounted for a substantial proportion of variance in outcomes ($\eta p^2 = 0.43$). Mean TMT-B completion times were numerically lower at follow-up in both groups, but no significant group-by-time interaction was observed. Participants in the NEG engaged

in structured recreational activities involving executive processes such as working memory, cognitive flexibility, and decision-making,[29] which may have contributed to descriptive changes over time; in inpatient settings, such cognitively engaging activities may support executive functioning and attenuate differences between groups. Conversely, although participants in the EG engaged in multicomponent physical training, the neuromotor and coordinative demands may not have been sufficiently specific or progressively cognitively challenging to produce additional measurable changes in set shifting,[30] particularly when baseline performance is already close to normative levels.[28] Taken together, these findings suggest that the absence of differential effects on executive outcomes may reflect relatively preserved baseline cognitive status, baseline demographic and clinical differences, and follow-up conditions.

Despite the absence of a significant group-by-time interaction, self-esteem improved over time in both groups. Similar to the cognitive findings, a plausible explanation for the lack of differential effects is the relatively high baseline level observed in both groups, suggesting a limited margin for detectable change. This pattern is consistent with a ceiling effect, which may reduce responsiveness to change.[31] Notably, baseline values were higher than normative averages reported for healthy adults,[32] which may appear counterintuitive in a psychosocially vulnerable inpatient population. One possible explanation is that the RSE captures global self-worth, which may remain relatively preserved or follow a different trajectory from domain-specific functioning in this context, potentially limiting its sensitivity to detect changes associated with exercise participation. This interpretation suggests that the observed pattern may reflect measurement characteristics rather than actual changes in psychosocial functioning, and is consistent with findings from Kulu et al.,[33] who reported greater improvements in samples with lower baseline self-esteem.

Among the outcomes assessed, craving (CCQ-Brief) was the only variable to show a significant group-by-time interaction in the primary analysis and represents the clearest finding of this study. In the exercise group, craving decreased markedly during the first five weeks and remained relatively stable thereafter. This finding is consistent with Wang et al.,[34] who reported reductions in craving following multicomponent exercise in individuals with heroin use disorder, supporting the plausibility that participation in structured exercise programs may be associated with craving reduction across substance use contexts. Although this pattern suggests an association with

participation in the exercise program, it should be interpreted cautiously given the observational design and baseline differences between groups. In the sensitivity analysis adjusted for age and duration of crack cocaine use, the difference in craving trajectories between groups became less pronounced, suggesting that baseline clinical characteristics may have contributed to the observed pattern over time.[11] These findings raise the possibility that age, duration of substance use, or clinical chronicity may influence craving trajectories or the response to exercise during inpatient treatment.

This study has several limitations. The sample included only adult men receiving inpatient care at a philanthropic mental health institution, which may limit generalizability to women and other treatment settings. The final sample reflected consecutive admissions and participant retention over a 10-week follow-up in a real-world inpatient context. No a priori sample size calculation was performed because this was a naturalistic study based on consecutive admissions and participant retention during follow-up. Because group classification followed routine clinical practice, the observed changes should be interpreted within the context of inpatient care, where abstinence, structured routines, and engagement in therapeutic or recreational activities may also have influenced outcomes. Baseline differences between groups, particularly in age, duration of crack cocaine use, and initial cognitive performance, should be considered when interpreting the findings. Although sensitivity analyses adjusted for age and duration of crack cocaine use were conducted, the group-by-time interaction for craving was attenuated after adjustment, suggesting that baseline differences may have partially influenced this finding. Analyses were based on complete cases, which may have introduced attrition bias given the substantial loss to follow-up. Although the selected instruments have evidence of validity, reliability, or normative applicability, formal responsiveness indices for all outcome measures in adults hospitalized for crack cocaine use disorder remain limited. This may have affected the interpretation of longitudinal changes, particularly for instruments with possible ceiling effects, such as the MMSE and RSE. In addition, subgroup analyses stratified by baseline self-esteem were not performed because of the small sample size and the risk of unstable estimates. Finally, the absence of post-discharge follow-up precludes evaluation of whether the observed changes were maintained after hospitalization. Future studies should include more diverse samples, longer follow-up

periods, and complementary outcome measures to further clarify these findings across different care contexts.

Conclusion

Participation in a multicomponent physical exercise program during inpatient care was associated with greater reductions in craving in the primary analysis, although this association was attenuated after adjustment for baseline group differences. Improvements in self-esteem and cognitive performance were also observed over time in both groups, without differences between participants who engaged in the exercise program and those who did not. Overall, these findings suggest that supervised multicomponent exercise may represent a feasible adjunct within multidisciplinary inpatient care, particularly for craving-related outcomes, and support further investigation in controlled longitudinal studies as a complementary, scalable, and low-cost strategy in addiction rehabilitation settings.

Ethical considerations

This study was approved by a local Research Ethics Committee (details blinded for review) and conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent prior to participation.

Data availability statement

The datasets generated and analyzed during the current study are not publicly available due to the sensitive nature of clinical data but may be available from the corresponding author upon reasonable request.

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Declaration of competing interests

The authors declare that they have no competing interests.

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