

1 **Inmates with harmful substance use increase both exercise** 2 **and nicotine use under incarceration**

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1 **Abstract**

2 Background: Exercise is increasingly understood as an important resource for people with harmful
3 substance use, including those in prison. Little is known about how inmates adopt various health
4 behaviors during incarceration, without interventions. Methods: This study analyzed self-reports from
5 1,468 inmates in Norwegian prisons, compared them according to harmful substance use pre-
6 incarceration, and explored changes in exercise and nicotine use during incarceration. Results were
7 presented in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology
8 (STROBE) guidelines. Results: Inmates with harmful substance use reported higher rates of smoking,
9 smokeless tobacco, and physical inactivity pre-incarceration than inmates without harmful use.
10 However, inmates with harmful use also exhibited more behavioral changes: they adopted exercise,
11 ceased smoking, and adopted smokeless tobacco at higher rates during incarceration than the non-
12 harmful group. Conclusions: Exercise is being taken up by a significant proportion of inmates, and may
13 in particular be a replacement behavior for substance use. However, unhealthy behaviors are also begun
14 or maintained. If prisons were used as an arena to facilitate healthy behaviors, the public health benefits
15 to a marginalized group such as substance-using inmates could be substantial.

16

17 **Keywords:** exercise, cigarette, smokeless tobacco, substance use, health behavior

18

19 **1. Introduction**

20 Exercise – defined as any planned, structured, or repetitive physical activities, often with the
21 goal of increased fitness [1] – is increasingly understood as an important resource for people struggling
22 with harmful substance use. Harmful substance use is indicated by damage to physical health, mental
23 health, or social functioning due to drug or alcohol use, and the danger of repeated use (in addition to
24 these harms) is the individual's physiological adaptation to substances [2]. A recent meta-analysis
25 reported that participation in an exercise intervention significantly increased the abstinences rate of
26 substance use disorder patients [3]. Numerous reviews have proffered clinical and theoretical
27 mechanisms for this efficacy, including less severe withdrawal symptoms during detoxification [3],
28 reduction in craving [4], lessened co-morbid anxiety and depression [3-5], improvement of positive

1 affect and mood [5], and reduction in stress reactivity [6] - overall reducing the chance of relapse among
2 people in treatment and afterwards. Exercise can also serve as an important alternative behavior, an
3 activity that takes up the time and energy otherwise consumed by substance use [7], and a majority of
4 people with substance use disorders are interested in assistance beginning or maintaining an exercise
5 regime [8].

6 The Norwegian health authorities [9] recommend exercise as an adjunct treatment for substance
7 use disorders because, in addition to clinical benefits, it is cost-effective and accessible after the formal
8 treatment system. Importantly, exercise reduces the risk of numerous preventable chronic diseases [10,
9 11], of which people with substance use disorders already experience earlier and with more fatal
10 consequences [12-15].

11 Despite this consensus, people with harmful substance use typically report far lower rates of
12 exercise than the general population [8]. This is true for out-of-treatment users, inpatients [16, 17], and
13 outpatients [16], with mixed evidence from inmates [18, 19]. Substance use disorders are the most
14 common mental disorders among inmates, with pooled estimates of a 51% prevalence of drug use
15 disorders worldwide, and a 24% prevalence of alcohol use disorder [20]. The restricted prison
16 environment and reduced access to illicit substances may spark a need to develop new coping
17 mechanisms and stress management techniques [21-23].

18 Prison can provide an ideal setting for exercise and other health behavior interventions, as the
19 inmates' exposure to interventions can be controlled [24, 25]. Many of the barriers to exercise identified
20 by substance users, such as a lack of time, transportation, or finances [8, 26] can be easily removed in
21 incarceration settings. Exercise interventions among inmates have increased fitness and functional
22 cardiorespiratory capacity [27-30], improved psychological well-being [21, 28, 31, 32], and reduced
23 aggression [33]. Only two of these studies reported on inmates with some sort of harmful substance use:
24 105 inmates with "substance abuse problems" pre-incarceration, no diagnosis reported, self-reported
25 improved physical fitness and alleviated anxiety, stress, and depression [28], and 19 inmates in
26 methadone maintenance treatment improved strength and cardiorespiratory capacity [30]. Few studies
27 have examined inmates' capacities to adopt exercise without interventions. Substance users in the UK
28 reported reductions in physical activity during the first week of incarceration [19], while cross-sectional

1 studies from Italy and Nigeria found both positive and negative relationships, respectively, between
2 exercise frequency and length of incarceration [34, 35].

3 In other naturalistic studies of incarceration settings, prisons are not realizing their health-
4 promotion potential as weight gain [36], and unhealthy diets are commonly reported [18, 37].
5 Furthermore, smoking is more prevalent among prisoners than the general populations in 35 of 36
6 countries [38], which one qualitative study suggests may be because smoking is perceived as one of the
7 few freedoms allotted to inmates [39]. A limitation of these studies is that they do not tell us how diets
8 and smoking behaviors changed during incarceration.

9 Data from the 1,499 inmates participating in the Norwegian Offender Mental Health and
10 Addiction (NorMA) study showed that 47% reported daily substance use in the six months prior to
11 incarceration, an important indicator of potentially problematic substance use [40]. Prisons may have
12 different health effects for substance-using and non-using inmates. In one study, inmates who used drugs
13 before incarceration are twice as likely to self-report better health after incarceration than inmates
14 without pre-incarceration drug use. For alcohol users, the pattern was reversed: the majority report
15 worsened self-rated health after incarceration [18].

16 Little research has been conducted that explores substance-using inmates' changes in multiple
17 health behaviors during incarceration, without interventions. This analysis therefore aims to answer the
18 following questions:

- 19 1. What is the prevalence of exercise and nicotine use among inmates with and without harmful
20 substance use?
- 21 2. How do exercise and nicotine use change over time?
- 22 3. Which variables, individual and system-related, are associated with increased exercise
23 frequency during incarceration?

24

25 **2. Materials and Methods**

26 *2.1 Setting*

27 Norway has some of the lowest incarceration rates in the world: 74 incarcerated persons per
28 100,000 residents, compared to 666 per 100,000 in the United States and 114 in Canada [41]. There are

1 63 prison locations, about two-thirds of which are high-security; capacity ranges from 13-400 cells, with
2 an average of 70 [42]. The Norwegian prison system is characterized by a rehabilitative perspective of
3 incarceration, in which incarceration should help individuals re-integrate into society by equipping them
4 with the tools to be participating citizens and to not re-offend [42, 43]. The loss of liberty shall be the
5 only deprived right, and incarcerated life should mirror life outside prison to as great as an extent
6 possible, which means that incarceration does not have a goal of making prisoners suffer [42]. Norway
7 also has a lower recidivism rate than most countries, estimated at 20% after two years [44].

8 Despite this success, the disproportionate burdens of mental and somatic multi-morbidities
9 borne by Norwegian inmates mirror those in the rest of the world [25, 45], and Norwegian inmates enter
10 with lower education levels and higher rates of unemployment than the general population [46]. In-
11 prison health care services do not seem to be available to all prisoners equally, according to an earlier
12 study including half of Norwegian prisons [47]. As an example, only thirteen prisons have specialized
13 SUD treatment units [42].

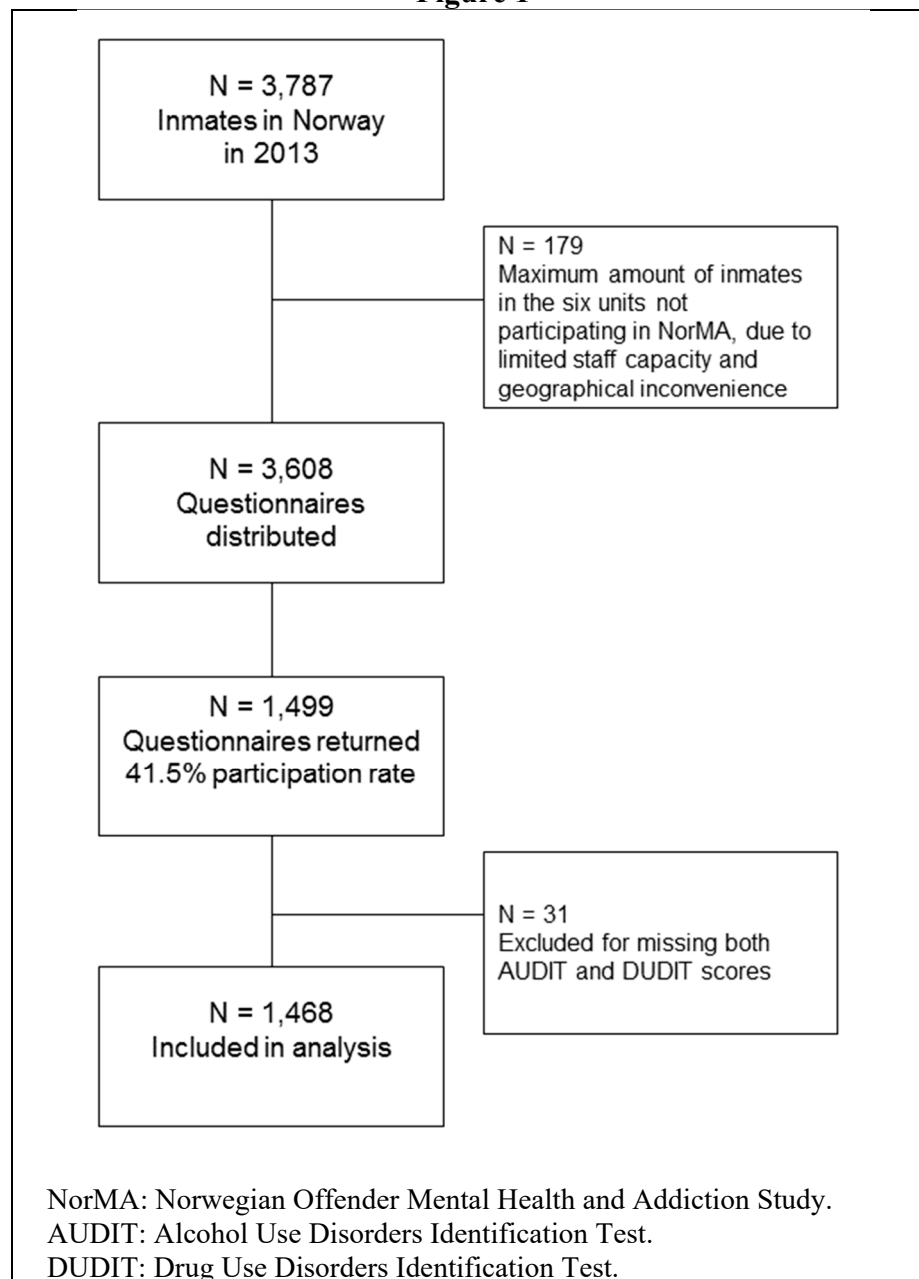
14 There is no national health promotion strategy for Norwegian prisons. Inmates are obliged to
15 engage in work and daily activities, such as school and other forms of education. However, they are not
16 obliged to exercise. Most prisons provide a gym, but exercise is usually based on the inmates' own
17 initiative. Only two prisons require light exercise, and only one has a complete cigarette ban. Cigarettes
18 and smokeless tobacco are typically available for purchase at prison commissaries, although cigarette
19 smoking has been banned in common areas in prisons since 2006 [42].

20 2.2 Study design

21 This cross-sectional analysis used a large cohort study of prisoners in Norway, the Norwegian
22 Offender Mental Health and Addiction (NorMA) study, the methodology of which has been described
23 in Bukten, Lund [48]. In the NorMA study, study investigators distributed questionnaires to 57 of 63
24 Norwegian prisons in 2013 and 2014, and collected self-reported survey data from 1,499 inmates of
25 high security units, low security units, and transitional facilities. There were no exclusion criteria, and
26 inmates participated based on their interest and availability. Figure 1 displays a flow chart of
27 participation.

1 The NorMA study received ethical approval by the Regional Committees for Medical and
 2 Health Research Ethics, the Norwegian Social Science Data Services, and the Directorate of Norwegian
 3 Correctional Service. Each prison's management approved all visits by researchers.

4 **Figure 1**



5 Figure 1 title: Flow chart of participation in the NorMA study

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7 2.3 Measures

8 The questionnaire included a total of 116 items and was available in Norwegian, English,
 9 German, French, and Russian.

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Six-month pre-incarceration variables

Participants were asked to answer the Alcohol Use Disorders Identification Test (AUDIT) and Drug Use Disorders Identification Test (DUDIT) by reflecting on their substance use in the twelve months prior to incarceration. Harmful alcohol use was indicated by a score of ≥ 8 or men and ≥ 6 for women on the AUDIT-10, according to Norwegian guidelines [49, 50]. Harmful drug use was indicated by ≥ 6 or men and ≥ 2 for women on the DUDIT [51]. Both the AUDIT and DUDIT were scored for those who answered at least five items in each, and these individuals' missing items were replaced by the individual means, following the recommendations of Hawthorne and Elliot [52]. Those who indicated through other questions that they had no experience with substances were instructed to skip the AUDIT and DUDIT, and were coded into the "no harmful use" group. Current psychological distress was measured by the ten-item Hopkins Symptom Checklist 10 (SCL10) on a 1-4 scale [53], in which scores ≥ 1.85 indicate clinical concern [54]. Due to missing data for the SCL10 (only 70.0% answered all ten items), the mean score was calculated with three missing values allowed, capturing an additional 10.1% of participants than if only participants with zero missing were assigned mean scores. Participants also reported if they exercised, the amount of exercise sessions per week, if they smoked cigarettes, and if they used smokeless tobacco in the six months prior to incarceration.

During incarceration variables

Participants were then asked to report the substances they had used during their current incarceration, and overall frequency of substance use. They also reported current exercise, cigarette use, and smokeless tobacco use. The smokeless tobacco products used in Scandinavia, "snus", have lower levels of nitrosamine than smokeless tobacco products sold in the United States and than in cigarettes [55]. Cigarette and smokeless tobacco reduction variables were created that captured changes in these behaviors over time while incarcerated, and coded on a scale from adoption to cessation: 0=began cigarette/smokeless tobacco use, 1=maintained, 2=stopped, and 3=never. Current self-rated physical health was reported on a 1-5 Likert type scale from 1=very poor to 5=very good, with 3 as a neutral option.

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2.4 Analysis

For this analysis, participants with harmful use of alcohol and/or drugs in the six months before incarceration were compared to those without harmful use. The two groups' independent variables displayed in Table 1 were compared by chi-squares, independent sample *t*-tests, and Mann U-Whitney tests, according to distribution and type of variable. All analyses were conducted with complete cases.

Several sets of chi-squares were then conducted to compare rates of pre-incarceration and during incarceration exercise, smokeless tobacco, and cigarette use between the two groups. To examine whether the two groups changed exercise, smokeless tobacco, or cigarette use behavior pre-incarceration to during incarceration, paired samples *t*-tests were conducted within each group to compare these dichotomous variables before and during incarceration. Changes in exercise frequency were explored further as the dependent outcome of a general linear model with repeated measures. Harmful substance use pre-incarceration was the between-subject factor and time the within-subject factor, accounting for individual variation in EX frequency from "pre-incarceration" to "during incarceration". Correlations with variables previously identified as influential were tested, including age, length of incarceration, and mental distress. Only mental distress had a weak relationship to current exercise frequency ($r = -.21$, $p < 0.001$), and was therefore not added as a covariate to the general linear model.

To explore potential factors associated with increased exercise frequency during incarceration, hierarchical multiple linear regression analyses were run separately for the harmful and non-harmful substance use groups. All bivariate relationships between exercise during incarceration and participant characteristics primarily describing current health states and behavior during incarceration (Table 1) were tested, as well as the relationships between reductions in cigarette smoking and smokeless tobacco use during incarceration. Pre-incarceration exercise frequency was entered in the first stage, followed stepwise by variables with significant bivariate relationships. Adjusted R^2 of each adjusted model are reported.

Results were presented in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [56].

1 3. Results

2 3.1 Sample description

3 Women comprised 6.4% (N=96) of the 1,468 participants. 73.7% (N=1,082) reported harmful
 4 substance use pre-incarceration, of which 63.6% reported daily use of at least one substance in the six
 5 months prior to incarceration. 26.3% (N=386) reported no harmful use before incarceration, of which
 6 2.3% (N=11) reported daily use. These two groups differed in most sociodemographic and substance
 7 use variables during incarceration (Table 1). Harmful substance users were on average five years
 8 younger and more likely to be single, were more often Nordic-born, and had lower rates of completed
 9 education and of employment or studying. They were also serving shorter sentences, and had been
 10 incarcerated for less time. Health variables during incarceration, however, did not differ; 66.2% of the
 11 harmful use group and 57.0% of the no harmful use group reported “good” or “very good” physical
 12 health, with 17.7% and 22.5% respectively, reporting “poor” or “very poor”. The average mental distress
 13 score was 1.93 in the harmful use group, with 45.0% scoring above the cut-off of 1.85, indicating
 14 clinically concerning symptoms. The average score in the no harmful use was below this threshold, and
 15 only 36.7% had clinically concerning symptoms.

Table 1: Description of 1,499 inmates, by pre-incarceration harmful substance use

	Harmful substance use, N=1,802 N (%)	No harmful substance use, N=386 N (%)	Test statistic	N missing
Women	65(6.0)	29 (7.5)	$X^2_{(1)}=1.08$	0
Age [mean (SD)]	32.8 (10.1)	38.8 (12.8)	$z=-9.04^{***}$	124
Nordic-born	837 (79.1)	201 (54.9)	$X^2_{(1)}= 80.56^{***}$	44
Secondary school or more	618 (57.8)	285 (74.8)	$X^2_{(1)}= 34.52^{***}$	18
Single	792 (73.9)	196 (52.0)	$X^2_{(1)}= 61.20^{***}$	18
Working or studying before incarceration	468 (43.3)	276 (71.5)	$X^2_{(1)}=90.83^{****}$	0
<u>Incarceration</u>				
Months of sentence (median, IQR)	13.0 (28.0)	27.9 (42.7)	$z=-4.15^{***}$	275
Months served (median, IQR)	4.5 (11.1)	6.0 (19.3)	$z=-2.67^{**}$	112
Security level			$X^2_{(2)}=4.48$	12
High-security	662 (61.5)	210 (55.3)		
Low-security	420 (39.0)	149 (39.2)		
Transitional housing	34 (3.2)	21 (5.5)		
<u>Health during incarceration</u>				
SCL10 score [mean (SD)]	1.93 (.79)	1.76 (.75)	$t_{(1189)}=-3.14^{**}$	277
Self-rated physical health			$X^2=-.26$	21
Very poor	53 (5.0)	34 (9.0)		

Poor	136 (12.7)	51 (13.5)	
Neither poor nor good	279 (26.1)	77 (20.4)	
Good	354 (33.1)	118 (31.3)	
Very good	229 (33.1)	97 (25.7)	
<u>Substance and unprescribed medication use during incarceration</u>			0
Frequency			$z=-7.06^{***}$
None	750 (69.3)	378 (97.9)	
Once	60 (5.5)	4 (1.0)	
2-3 times	72 (6.7)	2 (0.5)	
4+ times	200 (18.5)	2 (0.5)	
Cannabis	234 (21.6)	2 (0.5)	$X^2_{(1)}=93.96^{***}$
OMT medicine, e.g. methadone	168 (15.5)	2 (0.5)	$X^2_{(1)}=62.56^{***}$
Benzodiazepines or sedatives	123 (11.4)	1 (0.3)	$X^2_{(1)}=45.40^{***}$
Meth/amphetamines	69 (6.4)	0 (0)	$X^2_{(1)}=25.83^{***}$
Synthetic cannabis	43 (4.0)	0 (0)	$X^2_{(1)}=15.80^*$
Methylphenidate ^a , e.g. ritalin	39 (3.6)	0 (0)	$X^2_{(1)}=14.29^{***}$
Heroin	29 (2.7)	1 (0.3)	$X^2_{(1)}=8.33^{**}$
Cocaine	26 (2.4)	0 (0)	$X^2_{(1)}=9.44^{**}$
Gamma-hydroxybutyric acid (GHB)	20 (1.8)	0 (0)	$X^2_{(1)}=7.23^{**}$
Anabolic steroids	17 (1.6)	0 (0)	$X^2_{(1)}=6.14^*$
Inhalants	11 (1.0)	0 (0)	$X^2_{(1)}=3.95^*$
Ecstasy	9 (0.8)	0 (0)	$X^2_{(1)}=3.23$
LSD, PCP, or ketamine	7 (0.6)	0 (0)	$X^2_{(1)}=2.51$
² refers to chi-square for nominal dependent variables. z refers to Mann–Whitney U test for nonparametric variables. OMT: opioid maintenance treatment. ^a A central nervous system stimulant prescribed for attention-deficit hyperactivity disorder.			

1 *Table 1 legend: Inmates with harmful substance use before incarceration were younger, more likely to*
2 *be single, had lower rates of completed education and of employment or studying, and had a higher*
3 *prevalence of mental distress compared to inmates without harmful substance use.*

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5 3.2 Prevalence of exercise and nicotine use

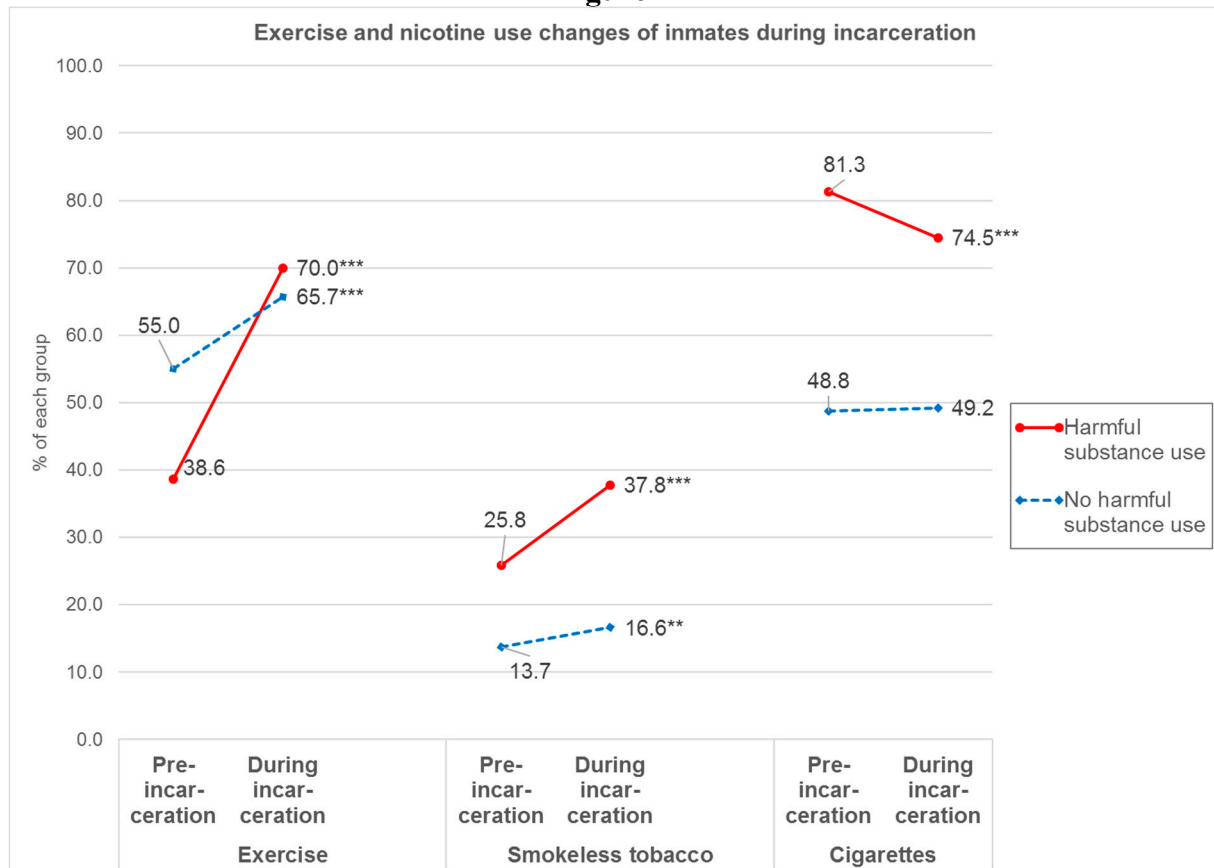
6 Figure 1 displays prevalence rates of the various health behaviors both pre-incarceration and
7 during incarceration. Prevalence of all three behaviors differed pre-incarceration (all p-values <0.001).
8 Harmful substance users were more likely to use both types of nicotine and less likely to exercise before
9 being incarcerated.

10 During incarceration (when interviewed), exercise rates increased among both groups, and the
11 increase in the harmful use group was so great that about two-thirds of both groups exercised, evening
12 out the pre-incarceration difference (p=0.123). Twice as many harmful substance users used smokeless
13 tobacco than the no harmful use group (p<0.001). Three quarters of harmful substance users smoked
14 cigarettes, while only one half of the no harmful use smoked (p<0.001).

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Figure 2



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3 Figure 2 title: Exercise and nicotine use changes of inmates during incarceration

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5 *3.3. Changes in exercise and nicotine use during incarceration*

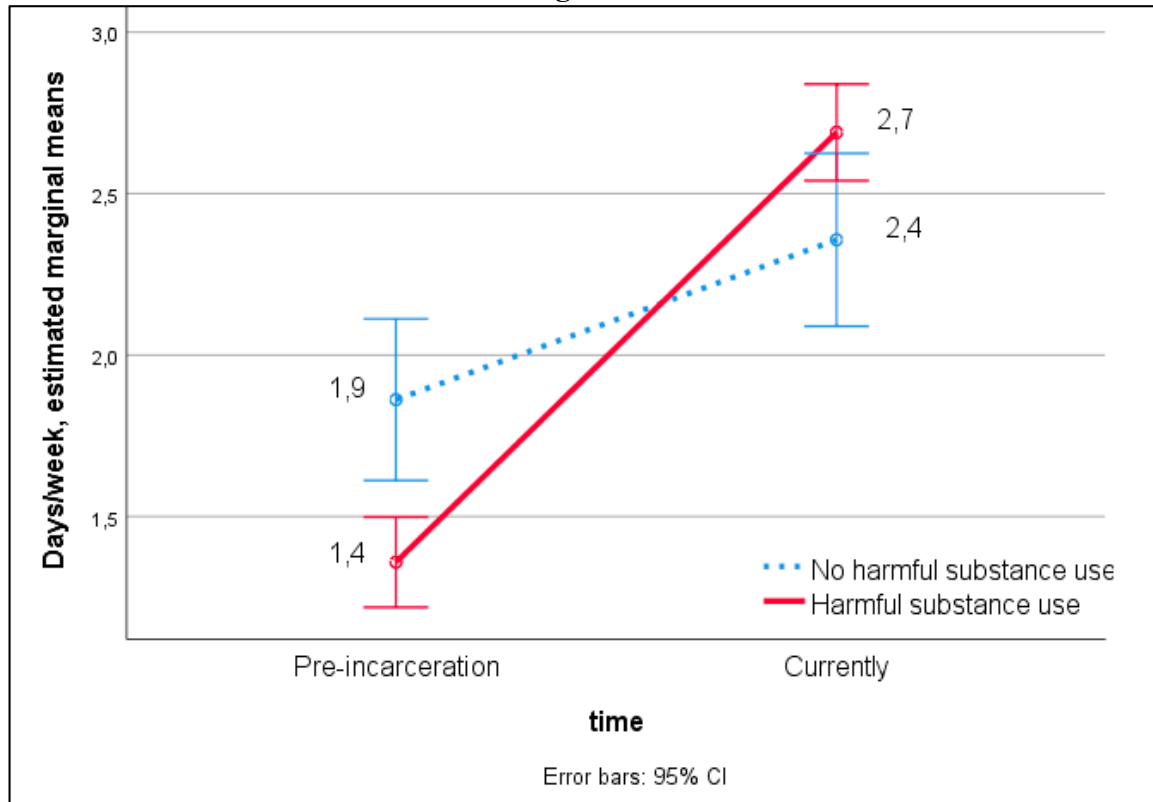
6 Figure 1 also displays changes in these behaviors during incarceration. Rates of exercise
 7 increased for both groups. Cigarette use decreased only among harmful substance users, while
 8 smokeless tobacco rates increased significantly for both groups.

9 The non-harmful use group reported pre-incarceration exercise at higher frequencies (1.9
 10 days/week) than the harmful use group (1.4 days/week); Figure 2. During incarceration, the cohort as a
 11 whole did not increase exercise frequency, with a non-significant main effect of time for the entire
 12 sample ($F[1, 1245]=97.2, p=0.072$). This increase was larger for the harmful substance use group, which
 13 increased from 1.4 to 2.7 days/week (significant interaction effect of group*time, $F[1, 1245]=20.4,$
 14 $p=0.016$).

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Figure 3



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4 Figure 3 title: Changes in exercise frequency (sessions/week) of inmates during incarceration

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6 *3.4 Factors related to increased exercise frequency*

7 Table 2 displays the results of the regression model explaining variance in exercise frequency

8 for the harmful substance use group. The regression equation was significant, $F(4, 563) = 34.9, p < 0.001$.

9 Four variables explained 19.0% of the variance in exercise frequency during incarceration, and the most

10 explanatory variable was self-rated physical health ($\beta = 0.299$). Pre-incarceration exercise frequency,11 added with forced entry into the model, was the next most important predictor ($\beta = 0.189$), while older12 age ($\beta = -0.141$) was a negative predictor. Having at least a secondary school education was also a13 positive predictor of higher exercise frequency ($\beta = 0.094$).

14 Anabolic androgenic steroid use, mental distress, reduction in cigarette use, and reduction in

15 smokeless tobacco were not significant predictors in the adjusted models. None of the other substances

16 used under incarceration had significant bivariate relationships exercise frequency.

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Table 2: Adjusted models explaining variance in exercise frequency during incarceration of inmates with harmful substance use

	Model ^a			
	1	2	3	4
(Constant)	---	---	---	---
Pre-incarceration exercise frequency	.251***	0.204***	0.190***	0.184***
Self-rated physical health		0.332***	0.304***	0.299***
Age			-0.132**	-0.141***
Secondary school education or higher				0.094**
<i>Adjusted R²</i>	<i>6.1%</i>	<i>16.8%</i>	<i>18.3%</i>	<i>19.0%</i>

*p<0.05, **p<0.01, ***p<0.001.

N=595. ^aSignificant bivariate variables not included in adjusted models: mental distress, reduction in cigarettes, reduction in smokeless tobacco, anabolic androgenic steroid use during incarceration, Nordic birth, months of sentence.

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2 For the non-harmful use group, five variables explained 22.7% of the variance of exercise
3 frequency during incarceration, in a significant regression equation ($F(3, 248) = 25.52, p < 0.001$). Pre-
4 incarceration exercise frequency was more important than for the harmful group ($\beta = 0.355$), while
5 satisfaction with physical health was nearly as important, and explained a stable amount of variance
6 with the inclusion of each new predictor variable ($\beta = 0.274$). Nordic birth was the only other positive
7 predictor ($\beta = 0.140$).

8

Table 3: Adjusted models explaining variance in exercise frequency during incarceration of inmates with no harmful substance use

	Model ^a				
	1	2	3		
(Constant)	---	---	---		
Pre-incarceration exercise frequency	0.387***	0.357***	0.355***		
Self-rated physical health		0.260***	0.274***		
Nordic birth			0.140*		
<i>Adjusted R²</i>	<i>14.6%</i>	<i>21.0%</i>	<i>22.7%</i>	<i>20.1%</i>	<i>21.1%</i>

*p<0.05, **p<0.01, ***p<0.001.

N=252. ^aSignificant bivariate variables not included in adjusted models: age, gender, smokeless tobacco reduction, cigarette reduction.

9

10 4. Discussion

11 Inmates with harmful substance use entered prison with higher rates of negative health behaviors
12 than inmates without problematic use, including 81.3% who smoked cigarettes, 61.4% who were
13 physically inactive, and 25.8% who used smokeless tobacco. However, inmates with harmful use also
14 exhibited more behavioral changes during incarceration: they adopted exercise, ceased smoking, and
15 adopted smokeless tobacco at higher rates during incarceration than the non-harmful group.

1 The significant positive change in exercise behavior among inmates with harmful substance use,
2 both in the amount of inmates beginning to exercise and in frequency, suggests that exercise may be an
3 important replacement behavior for substance use under incarceration. This replacement mechanism
4 could be a de facto replacement, as inmates have reduced access to substances: 18.5% of this group
5 reported substance use at least four times during incarceration, which is a clear decline from the 63.6%
6 daily use reported pre-incarceration. Exercise likely also induces neurological adaptations in reward-,
7 inhibition-, and stress-related systems that directly counter and compete with the effects of substances
8 in these same systems [57, 58].

9 Pre-incarceration exercise was found to predict current exercise and this was expected, as
10 exercise is a behavior in which within-person variation is decisive in predicting change. The low
11 correlation of current mental distress to current exercise frequency is promising, as it suggests that
12 mental health concerns need not be assumed prohibitive to inmate exercise. Muller and Clausen [59]
13 were similarly able to engage residential SUD patients with the highest mental distress in a pilot group
14 exercise program. Age negatively predicted exercise frequency for harmful substance users, but was
15 unrelated to non-harmful users' exercise. Mannocci, Mipatrini [35] also found exercise frequency in
16 Italian prisons to be negatively related to age, and positively related to physical health-related quality of
17 life and non-Italian nationality, with no relationship between exercise and amount of cigarettes or
18 education level. Furthermore, sentence duration was not an important predictor of exercise frequency in
19 our analysis, in line with Manocci et al.'s findings but not those of Olaitan, Shmaila [34] in Nigeria.

20 Previous longitudinal, population-based studies have found exercise uptake to result in
21 improved self-rated health [60], and exercise reductions in worsened self-rated health [61]. Similarly,
22 we found strong correlations of current exercise and current self-rated health among both inmate groups.
23 As with non-exercisers, inmates with poor health could be targeted as having potentially more to gain.
24 Exercise cannot change incarceration itself or elements such as overcrowding or a lack of healthcare,
25 but it could change the experience of incarceration, such as by providing a sense of autonomy, a
26 challenge to boredom, and a relief against stress, elements which have been identified as reasons for the
27 poor health of inmates [62]. Helping inmates exercise can also be seen as a way to equip them with an
28 anti-depressive and stress-reducing tool that they can continue to use post-release [63, 64]. One third of

1 inmates in a previous American study experienced an increase in depression and stress after release,
2 probably reflecting the environmental stressors of community living and the difficulties of post-release
3 reintegration [65]. Exercise could thus be a tool used not only during, but also after, incarceration.

4 It is important to emphasize that exercise should not be uncritically assumed a positive behavior.
5 Exercise will necessarily increase the risk for exercise-related physical injuries, for example, and health
6 screening may be necessary to identify prisoners with circulatory or heart problems who would benefit
7 more from low-intensity or otherwise modified exercise [66]. Meek and Lewis also speculate that some
8 prisoners with low self-esteem, eating disorders, or body disorders may be more predisposed to anabolic
9 steroid use if they begin exercising. Steroid use is associated with a range of adverse health
10 consequences, including cardiovascular effects and mental health problems [67-70], and lifetime
11 anabolic steroid use is already found to be many times higher among prisoners [71, 72] than the general
12 population [73]. These individuals could greatly benefit from learning that the positive effects of
13 exercise can be reached without steroids.

14

15 *4.1 Limitations and strengths*

16 Some of the limitations of this analysis arise from the data collected in the questionnaire, most
17 obviously that causation cannot be concluded from cross-sectional data. The cigarette and smokeless
18 tobacco variables were dichotomous, therefore we were not able to differentiate between casual smokers
19 or smokeless tobacco users from daily users. Similarly, lacking a standard definition of exercise,
20 participants' reports may not represent recommended amounts of exercise. Somatic health problems
21 were outside the scope of the NorMA study, and while the self-rated health question was likely a strong
22 proxy for health limitations, it was not possible to identify whether certain problems – for example,
23 cardiovascular disease or obesity – particularly inhibited the adoption of exercise.

24 The intention of this study was to collect participant-reported information. It is difficult to
25 predict whether a population will over- or under-report current exercise, according to a meta-analysis
26 [74], but self-reports of historical exercise, from 24 hours to 10 years earlier, have been reported to be
27 valid in numerous countries, although currently overweight individuals may over-report historical
28 exercise [75-77]. If certain groups over-reported pre-incarceration exercise, then exercise may have been

1 adopted during incarceration to an even greater extent than reported here. In general, participants in the
2 NorMA study were representative of the national prison population in terms of gender, citizenship, and
3 country of birth [48].

4

5 *4.2 Clinical implications*

6 An array of earlier literature has revealed the large health burden of substance users, such as
7 early onset cardiovascular disease and hypertension [78, 79]. The negative health behaviors documented
8 in this paper can, if modified, reduce many future health risks. Our findings strengthen the argument for
9 prisons to enable exercise as a public health intervention. Incarceration should be seen as an opportunity
10 for positive behavior change, and it is encouraging that inmates with pre-incarceration harmful substance
11 use seem particularly able to adopt such changes. Given that inmates' need for substance treatment far
12 outpaces access to treatment, actively facilitating exercise among inmates even without instituting
13 formal interventions – e.g. by increasing the amount of time available for exercise, preventing inmate
14 exclusion from facilities by other inmates, or resisting the revocation of exercise privileges as a
15 punishment measure – could be a cost-effective method to provide substance-using inmates with a
16 healthy alternative to substances. It may be particularly important to facilitate exercise among non-
17 exercisers entering prison, as this group may not have the health knowledge or self-efficacy to begin
18 independently, or may have health needs that require tailored or facilitative programs [66]. Prison staff
19 should be aware of lifetime steroid use and current steroid risk, such as harmful substance use and being
20 underweight [80], and future qualitative research among inmates should aim to understand the meanings
21 of steroid use, exercise, and other health behaviors explored in this article.

22

23 **5. Conclusion**

24 Overall, our results support the health-promoting potential and necessity of prisons: inmates
25 entered with high rates of negative health behaviors, and substance-using inmates were particularly
26 burdened. Behavioral change was common during incarceration, specifically the adoption of exercise
27 among inmates with problematic substance use, which may have been related to being deprived of
28 substances. Future research should explore the meaning of exercise for inmates and its potential to act

1 as a substitute behavior for substance use, while prisons themselves should facilitate a range of exercise
2 options, and institute nicotine cessation programs.

3

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11 **List of abbreviations:** NorMA: Norwegian Offender Mental Health and Addiction Study. AUDIT:
12 Alcohol Use Disorders Identification Test. DUDIT: Drug Use Disorders Identification Test. SCL10:
13 Hopkins Symptom Checklist 10. OMT: opioid maintenance treatment.

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