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Complete title: Exercise dependency and overuse injuries in Attention Deficit Hyperactivity Disorder.

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All authors have read and approved this paper for submission. All authors contributed to the conceptualisation of the study. AVR and EJD conducted analyses. All authors contributed to interpretation of findings and the initial draft with EJD revising the draft for submission. All authors consent to be held accountable.

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Exercise dependency and overuse injuries in Attention Deficit Hyperactivity Disorder

ABSTRACT

Attention deficit hyperactivity disorder (ADHD) is a common condition, but current medications have limitations, pushing a drive for alternative approaches. Different exercise-focused approaches have shown promise, but concern has also been raised about individuals with ADHD showing greater risk of addiction, including exercise dependency. Using an online survey, we examined current exercise practices, including exercise dependency and the presence of overuse injury, which could result from over-exercising, in 114 adults with ADHD. We found that most were regularly exercising. None were classified as exercise dependent, but 38.9% were deemed symptomatic non-dependent. Hyperactive-impulsive symptoms were a predictor of the level of exercise withdrawal experienced and the co-occurrence of Autism Spectrum Disorder was associated with greater risk of overuse injuries. The data indicate that ADHD may confer some greater risk of exercise dependency, aligning with previous studies investigating other addictions and suggesting further research is critical.

KEYWORDS

Addiction; Autism Spectrum Disorder; ADHD; Physical Activity

INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental condition, characterised by inattention, hyperactivity and impulsivity (American Psychiatric Association, 2022). Initially conceived as a childhood condition, it is now recognised to affect an estimated 2.58% of adults (Song et al., 2021). Consequences of ADHD are far-reaching and include learning, behavioural and emotional problems, lower occupational status, and relationships difficulties (Doggett, 2004; Faraone et al., 2000). Most adults with ADHD have co-occurring conditions; commonly depression and anxiety (De Graaf et al., 2008), Autism Spectrum Disorder (ASD) (Davis & Kollins, 2012), and various addictions, including behavioural addictions (Starcevic & Khazaal, 2017). Consideration of these co-occurring conditions is critical in managing ADHD.

The most effective treatment is stimulant medication (NICE, 2019), which reduces symptoms in 80% of individuals (Barkley et al., 1991; Dittmann et al., 2014; Milich et al., 2001). However, such treatment is not optimal. Issues include significant side effects (Mariani et al., 2007), residual symptoms (Aadil et al., 2017) and low adherence (Ishizuya et al., 2021). As such, there is a drive for alternative approaches, with exercise receiving considerable attention and recommendation in treatment guidelines (NICE, 2019). Whilst exercise can improve ADHD symptoms (Chang et al., 2012; Dinu et al., 2023; Jensen & Kenny, 2004; Piepmeier et al., 2015), concerns have been raised about exercise dependency and specifically withdrawal being greater in those with ADHD (Popat et al., 2021). Whilst the concept of exercise dependency or addiction is controversial and it is not classified as a disorder in the current DSM-5 or ICD-11, it has been argued to be an addiction (Berczik et al., 2012) and a measure of exercise dependency can be mapped on the seven factors associated with the substance dependence in DSM-IV, which remain in DSM-5 (Downs et al., 2004; Hausenblas & Downs, 2002). Similarly research has shown those exhibiting exercise dependency score higher on ADHD symptom scales, even if they have no difference in diagnosis (Colledge et al., 2022). The possibility of ADHD worsening withdrawal has been found for nicotine dependence and is thought to underpin difficulties those with ADHD have in quitting smoking (Bidwell et al., 2017; Sweitzer et al., 2018). However, previous research has been inconsistent as to whether it is the inattentive (IA) or hyperactive-impulsive (HI) symptoms (Ameringer & Leventhal, 2012; Bidwell et al., 2017) that link to withdrawal. Similar effects have not been found for cannabis (Chauchard et al., 2018). Other addictions have yet to be investigated.

Given the recommendations and interest in exercise to manage ADHD, and concerns about withdrawal from exercise, it is pertinent to investigate this further. Therefore, the primary aim of this study is to examine the association between ADHD and exercise dependence, specifically to identify which factors might predict exercise dependence as a whole and as individual symptom domains including withdrawal. Unlike the previous study examining this (Popat et al., 2021), the present study considers the role of three common co-morbidities (depression, anxiety and ASD). Additionally, given that exercise dependence is associated with over-training and injury, we aimed to investigate whether ADHD is associated with the presence of overuse injuries.

METHODS

Participants and procedures

Data were collected using an anonymous online survey (Feb 2022 - Mar 2023). Individuals could participate if they were ≥18 years, resident in the UK and had a diagnosis of ADHD, either alone or in combination with depression, anxiety, or ASD. Participants were recruited via advertisements on volunteer sites and social media. Those completing the survey had the option of entering a prize draw for a £50 shopping voucher by providing an email address on completion which was held separately to their survey data and could not be linked.

Measures

Participant characteristics

Participants provided demographic data for gender and age. They completed the 18-item Adult ADHD Self-Report Scale (ASRS) scoring statements from 0 (“never”) to 4 (“very often”) (Kessler et al., 2005). Total (18 items, $\alpha = .80$), inattention (IN, 9 items, $\alpha = .67$) and hyperactivity/impulsivity (HI, 9 items, $\alpha = .77$) scores were calculated (Das et al., 2012; Hines et al., 2012). Additionally, the score for the first six screener items was calculated ($\alpha = .73$) because a score ≥14 on these items is indicative of a diagnosis (Kessler et al., 2005; Kessler et al., 2007). Participants were asked to indicate if they were receiving medication and specify type (Stimulant, Non-stimulant, Other) and adherence using a previously adapted scale (Safren et al., 2007). Additionally, they were asked to state which, if any, of the three co-occurring conditions they had (depression, anxiety, ASD).

Exercise habits

Participants were asked to indicate whether they took part in weekly exercise and, if so, whether this was aerobic, non-aerobic or a mixture. To assess activity levels, the Godin Leisure-Time Exercise Questionnaire (GL-TEQ) was used (Godin, 2011). This requires participants to indicate how much they engage in strenuous, moderate, and mild exercise over a normal 7-day period. Participants indicate the number of 15-minute periods of exercise for each intensity level they complete within a typical 7-day period. For example, if someone typically runs for 60 minutes per week, they indicate 4 in the strenuous exercise question. A "leisure score index" or LSI is calculated by summing the weighted values ((9 × Strenuous) + (5 × Moderate) + (3 × Light)), such that a higher score indicates greater levels of activity and participants are categorised as "active" (LSI ≥ 24) or "insufficiently active" (LSI ≤ 23) based on this index (Godin, 2011). For all exercise questions, examples of relevant exercise were given to avoid ambiguity.

Exercise dependency

The Exercise Dependence Scale (EDS), which operationalises exercise dependence, has been shown to align with DSM-IV for substance dependence (Downs et al., 2004; Hausenblas & Downs, 2002; Ogden et al., 1997) and continues to align with the current DSM-5 criteria of substance dependence (American Psychiatric Association, 2022), was used. It consists of 21 items rated on a 6-point scale (1 = never, 6 = always). These items are summed to give a total score and divided into seven subscales corresponding to tolerance, withdrawal, intention effect, lack of control, time spent exercising, reduction in other activities and continuance despite problems. Higher scores indicate greater dependency. There are also established cut-off criteria to distinguish individuals deemed at risk of exercise dependence, symptomatic non-dependent, or asymptomatic non-dependent (Lindwall & Palmeira, 2009). Cronbach's alpha showed good internal consistency for whole scale ($\alpha = .94$) and subscales ($\alpha > .69$).

Overuse injuries

Overuse injuries were measured using the OSTRC Overuse Injury Questionnaire (Clarsen et al., 2013) which assesses four impacts of overuse through separate questions: pain, performance reduction, volume reduction and participation reduction. Questions are related to specific body parts, and we selected foot, ankle, lower leg, knee, upper leg, glutes, torso, arms, shoulder, and neck, allowing us to calculate averages for the upper and lower body score. We also calculated overall scores for the four components (pain, participation, volume, and performance). Participation and Pain are measured using a four-point scale (0 = Full participation/No pain, 8 = Full participation with problems/Mild pain, 17 = Reduced participation due to problems in area/Moderate pain, 25 = Cannot participate due to problems in area/Severe pain). Volume and performance are measured using a five-point scale (0 = No reduction, 6 = To a minor extent, 13 = To a moderate extent, 19 = To a major extent, 25 = Cannot participate at all).

Data Processing and analysis

The survey was completed by 173 individuals. Several exclusions were made before analysis. Firstly, any participants who omitted answers to a key question were removed (n = 29), leaving 144. Secondly, and given that we relied on self-report, we employed a cut-off score on the ASRS such that only participants scoring ≥14 on the screener items were retained with any below that being excluded (n = 18). This resulted in a final sample size of 126 participants. The sample was characterised using demographic, clinical and exercise measures using frequency counts (categorical variables) and means (continuous variables). To establish which factors predicted exercise dependence, separate linear regressions were used to predict the total EDS score and the scores of individual subscales corresponding to components of dependence. In each case a blocked regression was adopted with Block 1 containing demographic variables (age/gender), Block 2 adding LSI for activity level and Block 3 adding clinical measures (ASRS-IA, ASRS-HI, medication use, depression, anxiety, and ASD). Given the small number of participants in some gender categories, only those identifying as male or female were included, giving a sample size of 114. The same approach was used to establish which factors predicted overuse injuries with separate regressions run for lower body, upper body, pain, performance, participation, and volume. No prior study exists to estimate effect size for these analyses. However, previous work reported an effect size of $d = 0.44$ for increased withdrawal in ADHD (Popat et al., 2021), and as such we estimated sample size based on a medium effect size. A priori power calculations indicated that a sample size of 113 would be required to identify a medium effect in these analyses ($f=0.15$, power = 0.80, $\alpha = 0.05$).

RESULTS

Demographic and clinical traits

Most participants identified as female (N=94, 74.6%), followed by male (N=20, 15.9%), non-binary (N=10, 7.9%) or preferred not to say (N=2, 1.6%). The average age was 29.21 ± 8.20 (M ± SD) years. The total ASRS score was 55.07 ± 8.09 (M ± SD) with similar ASRS-IN (30.05 ± 5.71) and ASRS-HI scores (25.02 ± 5.71). All ASRS measures correlated (Total v. IN $r = .770$, $p < .001$; Total v. HI $r = .906$, $p < .001$; IN v. HI $r = .429$, $p < .001$). Seventy-eight individuals (61.9%) were taking medication, with 72 (57.1%) taking stimulants and two (1.6%) taking non-stimulants, one taking a combination (0.8%), two not specifying (1.6%) and one taking an anti-depressant (0.8%). Adherence information was provided by 64 participants and was 82.0% on average. Sixty-five (52%) participants reported having anxiety, 21 (17%) had ASD and 39 (31%) had depression. Only, 44 (34.9%) reported having ADHD alone, whilst 45 (35.7%) reported having a single co-occurring condition, 31 (24.6%) reported two co-occurring conditions and 6 (4.8%) reported having all three of the co-occurring conditions listed.

Exercise habits and dependency

Participant responses showed that the majority (N=112, 88.9%) undertook weekly exercise. Of these, 41 (36.6%) engaged in aerobic activity, 8 (7.1%) in non-aerobic activity and the remainder (N=63, 56.3%) completing a combination. All except two participants reported typical exercise intensity for their most common type of weekly exercise, with 50 (45.5%) reporting high intensity exercise, 54 (49.1%) indicating moderate intensity and just 6 (5.5%) reporting low intensity. Perhaps unsurprisingly given this, most participants (N=95, 75.4%) were classed as Active using the LSI and only 31 (24.6%) were Insufficiently Active. Table 1 provides the mean score for the Exercise Dependency Scale (EDS) total and subscales. Using the previously described method participants were categorised into different levels of risk (Lindwall & Palmeira, 2009). There were no dependent individuals but 49 (38.9%) were deemed symptomatic non-dependent and 77 (61.1%) were asymptomatic non-dependent.

Regression analysis for the overall EDS score found that demographic variables alone (Block 1) did not significantly predict exercise dependency, $F(2,111) = .152$, $p = 0.859$, but adding LSI (Block 2) did result in a significant model, $F(3, 110) = 5.087$, $p = 0.002$, which was not improved further by the addition of clinical measures (Block 3) $F(9, 104) = 2.318$, $p = 0.020$. The final model predicted 16.7% of the variance, with the only significant predictor of exercise dependency being the LSI i.e., activity level, which was a positive predictor (Table 2). A similar pattern of results was found for Withdrawal with the final model accounting for 19.5% of the variance, $F(9, 104) = 2.795$, $p = 0.006$, but here both LSI and ASRS-HI were significant positive predictors. For Tolerance, the same pattern was found, with the final model accounting for 20.8% of the variance, $F(9, 104) = 3.026$, $p = 0.003$) although LSI was the only significant predictor again. This was also the case for Time, $F(9,104) = 2.29$, $p = 0.022$, with 16.5%. For Intention only the second model was significant (Blocks 1 and 2) accounting for just 9.4% of the variance, $F(3, 110) = 3.811$, $p = 0.012$, with LSI as the only significant predictor. No models were significant for Continuance, Lack of Control or Reduction in Other Activities.

Overuse injury

Descriptive statistics for overuse measures are shown in Table 3. For upper body scores, linear regression revealed that all three models significantly predicted overuse injury with the final model accounting for 43.3% of the variance, $F(9, 104) = 2.663$, $p = 0.008$. Table 4 shows the significant predictors were age and ASD. A similar pattern was found for lower body scores, with the final model accounting for 38.4% of the variance, $F(9,104) = 2.005$, $p = 0.046$. Examination of the different components revealed slight variation on this pattern. Pain was not significantly predicted by models including only demographic (Block 1) or demographic and exercise (Block 2) variables but was significantly predicted when clinical variables were introduced, $F(9, 104) =2.386$, $p = 0.017$, although in the final model both age and ASD were significant predictors. For Performance, models at all three stages were significant, with the final model accounting for 15.9% of the variance, $F(9, 104)= 2.190$, $p = 0.028$, with age and ASD are significant predictors. The same pattern was found for training volume with 40.1% of the variance accounted for, $F(9, 104) = 2.219$, $p = 0.026$, and for participation, with the final model accounting for 18.6% of the variance, *F*(9, 104, 2.641, *p* = 0.009). In summary, increasing age and the presence of ASD, but not any ADHD symptoms, is also associated with greater injury.

DISCUSSION

The primary aim of this research was to examine the association between ADHD and exercise dependency. Our data revealed that most respondents were physically active. No participants met the criteria for exercise dependence. This is not unexpected given that estimates of dependence are as low as 3% (Orhan et al., 2019). However, we did find that around 40% were classed as symptomatic non-dependent i.e., the next level of risk. This is slightly lower than previously found for ADHD, which reported 54.2% (Popat et al., 2021), but nonetheless indicates that a significant proportion above the lowest risk level (non-symptomatic, non-dependent). Our analyses revealed, unsurprisingly, that activity level was a significant positive predictor of exercise dependency as a whole and of four of the seven DSM-IV criteria for substance dependence on which the EDS is modelled and persist in DSM-5: Withdrawal, Tolerance, Time spent on use and, Intention Effect. Critically, ASRS-HI, was also a positive predictor of withdrawal. This is consistent with previous work which showed that some individuals with ADHD have higher levels of withdrawal than those without the condition (Popat et al., 2021). It also aligns with other work that has indicated HI symptoms are positively correlated with nicotine withdrawal in healthy individuals (Bidwell et al., 2017) and that in those with ADHD, it is HI symptoms, not IA symptoms, that predict substance misuse (Elkins et al., 2007), and uptake of smoking (Fuemmeler et al., 2007). Collectively, these results suggest that the heightened withdrawal and risk of dependency related to HI symptoms in ADHD is not specific to nicotine and may also occur in exercise dependency.

The second aim of this research was to consider whether ADHD measures predict overuse injury, which might be expected if those individuals show greater signs of dependency. The results revealed that age was a significant predictor of all overuse measures. Much of the research to date on overuse injuries has focused on young or professional athletes which has therefore resulted in a relatively limited age range. However, one study which included a broader population did identify age as a risk factor (Trone et al., 2014) aligning with the current findings. Interestingly, there was no link between ADHD symptoms and overuse injury, but the presence of ASD was a significant positive predictor. The exact reasons for this are not clear. From the design of the current study, we cannot be certain whether the risk is associated with ASD *per* se or ASD when co-occurring with ADHD. Irrespective of this there are several reasons this might arise. For example, the greater risk could be associated with motor difficulties in ASD including weak neuromuscular interaction (Nadeem et al., 2021), or the restricted and repeated behaviours that can arise (Nekar et al., 2022), which may increase the risk of overuse injury. Recent research has indicated that individuals with ASD also often show symptoms of hypermobility (Nisticò et al., 2022), although it is unclear that being hypermobile increases risk of overuse injury (De Smet et al., 1998; Junge et al., 2015). Given the high co-occurrence of ASD and ADHD, it is important to investigate any links with overuse injury further before recommending exercise as a management strategy in ADHD.

This work should be interpreted in line with its strengths and limitations. Although the data was collected using an anonymous online survey, which would encourage honesty, participants did self-reported their ADHD diagnosis, albeit in a way that we could confirm with an established screening survey (Kessler et al., 2005; Kessler et al., 2007). However, we did not verify their diagnosis or ADHD, or any co-morbidities, with a structured clinical interview, which can be seen as a limitation. Despite this, it should be noted that the final sample had the characteristics of an ecologically valid group of the population with ADHD, evidenced through inclusion of those with common co-morbidities at similar rates to be expected in the general population with ADHD (Davis & Kollins, 2012; De Graaf et al., 2008) and adherence at rates typical of individuals with ADHD who take medication (Safren et al., 2007). Whilst the sample was restricted to those residing in the UK and female-dominated, it does exceed the required size to obtain adequate power as per our power calculations the latter could be considered a strength given the male-dominated research in ADHD (Dinu et al., 2022). It is noteworthy that over 80% of our sample undertook weekly exercise, which is higher than typically reported for the general population (Sport England., 2022). This could be indicative of self-selection bias, or it could reflect the fact that those with ADHD may be more physical activity than those without (Weissenberger et al., 2018). Additionally, whilst we relied on self-report which could be considered a limitation, previous research has suggested that this can be reliable if answers are known to individuals, questions are unambiguous and relate to recent activities, require a thoughtful response and will not lead to undesirable disclosures (Kuh, 2001; Owston et al., 2011). Finally, given the anonymous survey data collection, it is possible that individuals could have completed the survey multiple times. Examination of the data indicate that this was not the case, but future studies should utilise different techniques to avoid this.

CONCLUSIONS

Given the need for alternative interventions in ADHD, and the potential of exercise to be utilised, it is critical, we fully understand any associated risks. The current study adds to mounting evidence that individuals with ADHD may experience greater withdrawal from exercise than those without and suggests that it is the HI symptoms that are central to this. Additionally, the presence of ASD was associated with overuse injury. The exact reasons for this are unclear but warrant further investigation.

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Table 1. Exercise dependency measures for the sample, as a whole and broken down into the 7 components of addiction according to the DSM.

Scale/Subscale	Mean (SD)
Total Exercise Dependency	41.34 (12.75)
Withdrawal	8.10 (2.47)
Continuance	5.80 (2.34)
Tolerance	6.25 (2.54)
Lack of Control	4.94 (2.36)
Reduction in other activities	5.17 (2.03)
Time	5.47 (2.46)
Intention	5.60 (2.28)

Table 2. Coefficients of significant predictors for different components of exercise dependency.

Independent Variable Significant predictors	R^2	b	β	*t* (*p*)
Exercise Dependency	.167			
LSI		9.828	0.341	3.671 (<0.001)
Withdrawal	.195			
LSI		1.828	0.338	3.702 (<0.001)
ASRS-HI		0.096	0.222	2.200 (0.030)
Tolerance	.208			
LSI		2.536	0.527	4.814 (<0.001)
Time	.165			
LSI		1.861	0.510	3.652 (<0.001)
Intention	.094			
LSI		1.549	0.507	3.054 (<0.001)

Table 3. Overuse injury measures from the OSTRC survey for the sample

Scale/Subscale	Mean (SD)
Upper Body	6.50 (10.19)
Lower Body	5.99 (9.43)
Participation	1.88 (3.22)
Volume	1.28 (3.09)
Performance	1.22 (0.53)
Pain	1.83 (2.93)

Table 4. Coefficients of significant predictors for different components of overuse injury.

Independent Variable Significant predictors	R^2	b	β	*t* (*p*)
Upper Body	.187			
Age		0.269	0.127	2.824 (0.006)
ASD		6.109	0.253	2.824 (0.006)
Lower Body	.148			
Age		0.199	0.222	2.348 (0.021)
ASD		3.952	0.188	2.054 (0.042)
Pain	.414			
Age		0.053	0.190	2.040 (0.044)
ASD		1.508	0.232	2.572 (0.012)
Participation	.186			
Age		0.093	0.299	3.234 (0.002)
ASD		1.760	0.241	2.689 (0.008)
Volume	.161			
Age		0.069	0.244	2.592 (0.011)
ASD		1.284	0.193	2.123 (0.036)
Performance	.399			
Age		0.012	0.236	2.512 (0.014)
ASD		0.246	0.219	2.403 (0.18)