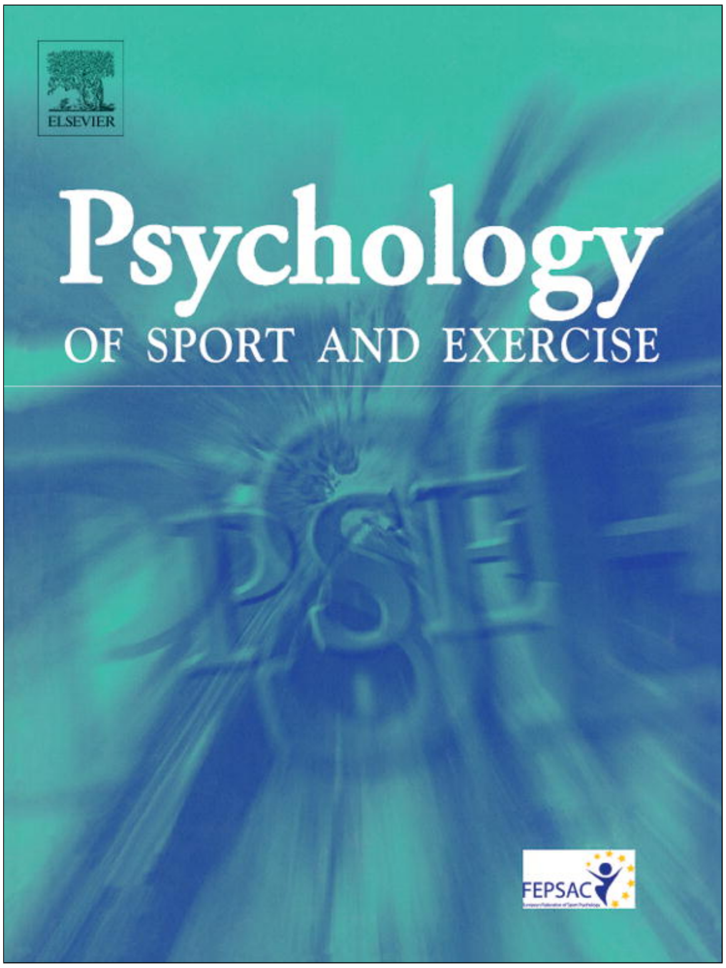
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# Psychometric properties and concurrent validity of two exercise addiction measures: A population wide study

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A R T I C L E I N F O

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A B S T R A C T

*Objectives:* The existence of exercise addiction has been examined in numerous studies. However, none of the measures developed for exercise addiction assessment have been validated on representative samples. Furthermore, estimates of exercise addiction prevalence in the general population are not available. The objective of the present study was to validate the Exercise Addiction Inventory (EAI; Terry, Szabo, & Griffiths, 2004), and the Exercise Dependence Scale (EDS; Hausenblas & Downs, 2002b), and to estimate the prevalence of exercise addiction in general population.
*Design:* Exercise addiction was assessed within the framework of the *National Survey on Addiction Problems in Hungary* (NSAPH), a national representative study for the population aged 18–64 years ($N = 2710$).
*Method:* 474 people in the sample (57% males; mean age 33.2 years) who reported to exercise at least once a week were asked to complete the two questionnaires (EAI, EDS).
*Results:* Confirmatory Factor Analysis (CFA) indicated good fit both in the case of EAI (CFI = 0.971; TLI = 0.952; RMSEA = 0.052) and EDS (CFI = 0.938; TLI = 0.922; RMSEA = 0.049); and confirmed the factor structure of the two scales. The correlation between the two measures was high ($r = 0.79$). Results showed that 6.2% (EDS) and 10.1% (EAI) of the population were characterized as nondependent-symptomatic exercisers, while the proportion of the at-risk exercisers were 0.3% and 0.5%, respectively.
*Conclusions:* Both EAI and EDS proved to be a reliable assessment tool for exercise addiction, a phenomenon that is present in the 0.3–0.5% of the adult general population.


## Introduction

To promote and maintain health, the current guidelines of the U.S. Department of Health and Human Services (2008) recommends that adults should engage in 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic physical activity in a week or an equivalent combination of moderate- and vigorous-intensity aerobic activity. The recommendation also state that additional and more extensive health benefits could be reached by increasing the physical activity up to 300 min a week of moderate-intensity or 150 min a week of vigorous intensity.

This and other recommendations (e.g., Haskell et al., 2007) may justify even large doses of physical activities as personally and socially responsible behaviours. However, as a possible consequence at times of psychological and/or emotional hardship, a number of habitual exercisers may engage in such activity as a form of escape. In these cases, physical activity may be exacerbated as a form of coping mechanism, while using (consciously or subconsciously) the justification for the high volumes of exercise as a psychological defence mechanism, known as rationalization (Cramer, 2006). The reliance on exercise as a means of coping with adversity has the potential become obsessive as well as compulsive

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(Allegre, Souville, Therme, & Griffiths, 2006). Associated with increased tolerance, overexercising may lead to physical injuries, reversible or even irreversible health consequences, and mortality (Cumella, 2005). The scholastic literature started to pay attention to ill patterned exercise behaviours for over 30 years (e.g., Morgan, 1979). Overexercising to the point where one loses control over the exercise routine and walks a "path of self-destruction" (Morgan, 1979) was termed *exercise addiction* (e.g., Griffiths, 1997; Thaxton, 1982), or *exercise dependence* (e.g., Cockerill & Riddington, 1996; Hausenblas & Downs, 2002a). Due to the multidisciplinary nature of the literature regarding problematic exercise, different research orientations use several incongruent terminologies in the discussion of the excessive exercise syndrome. This includes the two screening instruments compared in the present study (i.e., the "Exercise Addiction Inventory" and the "Exercise Dependence Scale"). In this paper a theoretical assumption was made that the two instruments are attempting to assess the same phenomenon. A recent comprehensive review examining the literature on problematic exercise use came to the conclusion that the most appropriate term to use is 'exercise addiction' because it incorporates both 'dependence' and 'compulsion' (Berczik et al., 2012). However, most researchers in the field use the terms 'exercise addiction', 'exercise dependence' and 'compulsive exercise' to mean the same thing. In this paper, the term 'exercise addiction' is used throughout based on the arguments of Berczik et al., (2012).

*Epidemiology of exercise addiction*

To date, studies of exercise addiction prevalence have been carried out upon American and British samples of regular exercisers. In five studies carried out among university students, Hausenblas and Downs (2002b) reported that between 3.4% and 13.4% of their samples were at high risk of exercise addiction. Griffiths, Szabo, and Terry (2005), reported that 3.0% of a British sample of sport science and psychology students were identified as at-risk of exercise addiction. These research-based estimates are in concordance with the argument that exercise addiction is *relatively* rare (Szabo, 2000; de Coverley Veale, 1995) especially when compared to other addictions (Sussman, Lisha, & Griffiths, 2011). Nevertheless, given the severity of the problem, even a tenth of positive diagnosis among the high risk cases may be large (i.e., 0.3% is 30/10,000 cases).

Among those who are also professionally connected to sport, the prevalence may be even higher. For example, Szabo and Griffiths (2007) found that 6.9% of British sport science students were at risk of exercise addiction. However, in other studies where more involved exercisers were studied much higher estimates have generally been found. Blaydon and Lindner (2002) reported that 30.4% of triathletes could be diagnosed with primary exercise addiction, and a further 21.6% with secondary exercise addiction. In another study, 26% of 240 male and 25% of 84 female runners were classified as "obligatory exercisers" (Slay, Hayaki, Napolitano, & Brownell, 1998). Lejoyeux, Avril, Richoux, Embouazza, and Nivoli (2008) found that 42% of clients of a Parisian fitness room could be identified as exercise addicts. Recently, he reported lower rates of just under 30% (Lejoyeux, Guillot, Chalvin, Petit, & Lequen, 2012). However, one study that surveyed 95 'ultra-marathoners' (who typically run 100 km races) reported only three people (3.2%) as at-risk for exercise addiction (Allegre, Therme, & Griffiths, 2007).

It is clear that besides differences in the applied measures and criteria, these appreciable differences in the estimates could be attributed to the sample selection, small sample size, and the sampling method. With the exception of the study by Lejoyeux et al. (2008) that applied consecutive sampling, all the studies to date have used convenience sampling. Furthermore, clear definitions of the target population are lacking in most cases. As a consequence, the estimates of these studies are in no way comparable, and to draw any general conclusions of these prevalence figures of exercise addiction is very much limited. Therefore, there is a demonstrable need for reliable estimates on the extent of exercise addiction in the general population and in properly defined populations of regular exercisers.

*Measures and their theoretical background*

Evidently, the conceptual definition of exercise addiction needs to be standardized with those of other addictions. Relying on Goodman's (1990) description, addiction is a behavioural process that can provide either pleasure or relief from internal discomfort (e.g., stress, anxiety) and it is characterized by repeated failure to control the behaviour (i.e., state of powerlessness), and maintenance of the behaviour despite major negative consequences. Clearly, *lack of control* and *negative consequences* (with various severity and outcome) are additional classifying components of the disorder. Griffiths (2005) proposed a modified "components" model for addictions based on the earlier work of Brown (1993). The model is not exclusive to exercise addiction, but it aligns the latter with other addictions that share six core symptoms: 1) *salience*, 2) *mood modification*, 3) *tolerance*, 4) *withdrawal*, 5) *conflict*, and 6) *relapse*. Griffiths suggests that addictions, in general, are part of a biopsychosocial process and evidence is growing that most – if not all – addictions seem to share these components or symptoms.

These six core components of addictive behaviour served the theoretical foundation for the Exercise Addiction Inventory (EAI – Terry et al., 2004). The EAI is a short, psychometrically validated questionnaire that comprises only six statements, each corresponding to one of the symptoms in the "components" model of addiction (Griffiths, 2005). Each statement is rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The EAI cut-off score for individuals considered at-risk of exercise addiction was defined originally as 24 (i.e., most answers agree or strongly agree with the presence of the six classical symptoms), and 13 for those considered being symptomatic nondependent exercisers. However, these cut-off points were never tested psychometrically. The EAI was developed on the basis of a sample of 200 habitual exercisers in the United Kingdom. The internal reliability of the original scale was excellent ($\alpha = 0.84$) and its concurrent validity was at least $r = 0.80$.

Hausenblas and Downs (2002a, 2002b) developed the Exercise Dependence Scale (EDS) using an American sample. The Exercise Dependence Scale was based on the Diagnostic and Statistical Manual of Mental Disorder-IV criteria for substance dependence (DSM IV – American Psychiatric Association [APA], 2000). The EDS yields both interval and nominal data. Specifically, a mean score (i.e., interval data) as well as categorization (i.e., nominal data) are obtained. This latter solution is to differentiate between at-risk, nondependent-symptomatic, and nondependent-asymptomatic individuals. The categorization into one of the three groups are generated by a scoring manual that consists of flowchart decision rules, in which items or combination of items determine into which group the person is classified. On the EDS, 21-items are rated on a 6-point frequency scale ranging from 1 (*never*) to 6 (*always*). Evaluation is made in reference to the DSM-IV criteria (APA, 2000), screening for the presence of three or more of the following symptoms: 1) *tolerance*, 2) *withdrawal*, 3) *intention effects*, 4) *loss of control*, 5) *time*, 6) *conflict*, and 7) *continuance*. A total score and subscale scores can be calculated for the EDS. The higher the score, the higher is the risk for addiction. The EDS possesses good psychometric properties, including a good internal reliability

($\alpha$ = 0.78 to $\alpha$ = 0.92), test–retest reliability ($r$ = 0.92), and concurrent validity with the EAI ($r = 0.81$).

The EAI and the EDS are perhaps the most recent and most widely used screening tools in the research area of exercise addiction, primarily because of their superior psychometric properties in contrast to their antecedent instruments, secondarily because of their theoretical underpinning. Although the tools differ in length and the underlying approach for screening, their excellent concurrent validity suggests a good internal validity for both scales (Allegre et al., 2006). It is important to note that the two instruments were based on culturally different samples (British and American). Further, it is also important to note that these tools, to date, have not been adopted in a population-wide study.

### *Aims of the study*

To the authors' knowledge, no national prevalence survey on exercise addiction has ever been published, and no study has ever compared and validated the two most used problematic exercise scales (i.e., the EAI and EDS) using robust samples. The aims of the present study were therefore threefold. The first aim was to psychometrically validate the EAI and the EDS and to define the cut-off score of the EAI based on empirical analysis using EDS as 'gold standard'. The second aim was to evaluate whether these two tools are feasible to use in a general population study. The third – and perhaps most important – aim was to estimate the prevalence of exercise addiction at a general population level as well as in a well-defined exercising population. As noted above, prevalence estimates of special population studies vary greatly, mainly due to the lack of operational definition concerning the examined population and/or the unsatisfactory sampling methods. In the present general population study in Hungary – which as far as the authors are aware is the first national prevalence study ever worldwide in the area of exercise addiction – a sophisticated sampling method was utilized in order to receive convincing and reliable data. Moreover, validation of these two tools makes the assessment of exercise addiction possible with a reliable and comparative method. Given the fact that no study has ever used these measures on a nationally representative sample or have assessed the psychometric properties using samples such as those used here, the approach was necessarily exploratory (and therefore has no specific hypotheses).

## Method

### *Participants and procedure*

Exercise dependence was assessed within the framework of the *National Survey on Addiction Problems in Hungary* (NSAPH) (Paksi, Rózsa, Kun, Arnold, & Demetrovics, 2009). In this survey, in addition to the assessment of chemical addictions (i.e., tobacco smoking, alcohol and other psychoactive substance use) various behavioural addictions such as pathological gambling, internet addiction, compulsive buying, eating disorders, work addiction, exercise dependence and compulsive skin picking were also assessed.

The target population of the survey was the total population of Hungary between the ages of 18 and 64 (6,703,854 persons). The sampling frame consisted of the whole resident population with a valid address, according to the register of the Central Office for Administrative and Electronic Public Services on January 1, 2006 (6,662,587 persons). Data collection was executed on a gross sample of 3183 people, stratified according to geographical location, degree of urbanization and age (overall 186 strata) representative of the sampling frame. Participants were surveyed using the so-called 'mixed-method' via personal visits. Questions regarding background variables and introductory questions referring to specific disorders were asked in the course of face-to-face interviews, while symptom scales, including the Exercise Addiction Inventory (EAI) and Exercise Dependence Scale (EDS), were applied using self-administered paper-and-pencil questionnaires. These questionnaires were returned to the interviewer in a closed envelope to ensure confidentiality. The net sample size was 2710 (response rate: 85.1%). The ratio of samples belonging to each strata was adjusted to the characteristics of the sampling frame by means of a weighted matrix for each stratum category. The weights applied have normal distribution (SD: 0.228; Skewness: 0.639; Std. Error of Skewness: 0.047; Kurtosis: 2.397; Std. Error of Kurtosis: 0.094).

Those participants were asked to fill out the two exercise dependence questionnaires who were regular exercisers at least on a weekly basis according to the study's screening question. This subsample comprised 474 participants (270 males and 204 females) with a mean age of 33.2 years (SD = 12.1).

## Measures

### *Demographic data*

Data were collected on age, gender, education level, employment status, and level of deprivation. A Deprivation Index was applied according to Townsend's multi-dimensional disadvantage and deprivation theory (Townsend, 1979), which emphasizes the fact that the financial status of individuals and families can only be accurately measured via analysis of a complex set of living conditions. The index applied in this study is based on 16 living condition components (Spéder, 2002) and was formed by averaging the answers, indicating where components were missed due to financial reasons.

### *Exercising*

Exercise activity was measured by asking the participants to list all sports and physical activity they engaged in and how frequently these were engaged in.

### *Exercise Addiction Inventory*

(EAI, Terry et al., 2004): This measure is a theory-based short measurement tool comprising six statements, that were designed to be indicative of core addictive behaviour components. Each item is rated on a five-point Likert-scale (1 = strongly disagree; 5 = strongly agree). The EAI was originally translated and published into the Hungarian language by Demetrovics and Kurimay (2008).

### *Exercise Dependence Scale-21*

(EDS, Hausenblas & Downs, 2002b). This is a multidimensional theoretical-based measure of exercise-dependence symptoms and was translated into Hungarian by Demetrovics and Kurimay (2008). The items refer to current exercise beliefs and behaviours. The response options were on a 6-point Likert-type scale ranging from 1 (never) to 6 (always). A higher score reveals more exercise dependence symptoms (Downs, Hausenblas, & Nigg, 2004).

## Data analysis

The present study sought to examine the factorial and the concurrent validity of the two different exercise addiction inventories, namely the AEI and the EDS. Confirmatory factor analyses

(CFA) were performed separately with both measures with MPLUS 6.0 and robust maximum-likelihood estimation (MLR) was used that is robust to non-normality (Muthén & Muthén, 2007). Multiple criteria were applied to measure the goodness-of-fit in CFA. A satisfactory degree of fit requires the *comparative-fit-index* (CFI) and the Tucker–Lewis Index (TLI) to be close to 0.95, and the model should be rejected when these indices are $<0.90$ (Brown, 2006). The next fit index was root-mean-square error of approximation (RMSEA). RMSEA below 0.05 indicates excellent fit, a value around 0.08 indicates adequate fit, and a value above 0.10 indicates poor fit. Closeness of model fit using RMSEA (CFit of RMSEA) is a statistical test (Browne & Cudek, 1993) that evaluates the statistical deviation of RMSEA from the value 0.05. Non-significant probability values ($p > 0.05$) indicate acceptable model fit, though some methodologists would require larger values such as $p > 0.50$ (Brown, 2006). The last fit index is the standardized root mean square residual (SRMR). An SRMR value below 0.08 is considered a good fit (Kline, 2005). Factor determinacy values were also calculated. The factor score determinacy is the correlation between the estimated and true factor scores. It ranges from zero to one, and describes how well the factor is measured by the observed indicators (Muthén & Muthén, 2007). Internal consistencies were assessed by Cronbach's $\alpha$, which was considered satisfactory if the values were at least 0.70 (Nunnally & Bernstein, 1994).

For sensitivity analysis based on EDS as a gold standard, the sensitivity and specificity values were calculated for several EAI cut points. The accuracy of the EAI can be assessed by calculating the proportion of cases who are individuals classified non-dependent symptomatic or at-risk by the EDS, and non-cases, that is, putatively healthy participants who are classified asymptomatic by the EDS. Sensitivity (i.e., the proportion of true positives that are correctly identified by the EAI) and specificity (i.e., the proportion of true negatives that are correctly identified by the EAI) were defined based in the suggested by Altman and Bland (1994a) and Glaros and Kline (1988). In order to explore the probability that the EAI will give the correct "diagnosis", the positive predictive values, the negative predictive values, and the accuracy values were calculated for several EAI cut points. Positive predictive value (PPV) was defined as the proportion of patients with positive test results who are correctly diagnosed (Altman & Bland, 1994b; Glaros & Kline, 1988). Negative predictive value (NPV) was defined as the proportion of patients with negative test results who are correctly diagnosed (Altman & Bland, 1994b; Glaros & Kline, 1988).

A receiver operating characteristic curve analysis (ROC analysis) was obtained by plotting sensitivity (true positive test results) against the false positive rate ($1 -$ specificity) for all possible EAI cut-off points. This curve is the plot of all of the sensitivity/specificity pairs resulting from continuously varying the decision threshold over the entire range of results observed, thus it is the comprehensive representation of pure accuracy (Zweig & Campbell, 1993).

## Results

### *Characteristics of the sample*

A total of 474 participants (17.5% of the examined population) reported exercising at least on a weekly basis. They comprised 270 males (57%) and 204 females with a mean age of 33.2 years (SD = 12.1). 176 people (37.3%) were married, 50 (10.6%) were in a relationship, 41 (8.6%) were divorced or widowed, and 205 (43.4%) were not in any relationship. (Two participants [0.5%] did not provide any data on this variable.) In relation to educational status, 87 participants (18.3%) had less than high school education, 170 (35.8%) had finished high school education, and 318 (45.9%) had college or university education. Using three categories of deprivation index indicating the owning properties, 153 (32.3%) were not deprived, 205 (43.2) had medium level of deprivation, and 116 (24.5%) had the most severe deprivation level. In relation to occupational status, 301 people (63.6%) were employed, 39 (8.3%) were unemployed, 81 (17.1%) were students, 25 (5.4%) were retired, 7 (1.5%) reported that they were unable to work, and 20 (4.2%) did not provide an answer to the question.

### *Confirmatory factor analysis of the Exercise Addiction Inventory (EAI)*

A confirmatory factor analysis was performed with the six items of the EAI in the regular exercisers ($N = 465$), and tested the one-factor solution. The fit indices indicated good fit ($\chi^2 = 20.2$ df $= 9$ $p = 0.016$; CFI $= 0.971$; TLI $= 0.952$; RMSEA $= 0.052$ [0.021–0.082]; Cfit $= 0.418$; SRMR $= 0.029$). No modification indices were found above the minimum value. Factor loadings overall were moderate in the 0.38 to 0.72 range and they are presented in Table 1. This one-factor solution clearly confirms the theoretically proposed structure of this scale. Internal consistency was adequate in this sample (Cronbach $\alpha = 0.72$).

### *Confirmatory factor analysis of the Exercise Dependence Scale-21 (EDS)*

To examine the factor structure of the EDS, a confirmatory factor analysis was performed to test the original 7-factor solution ($N = 458$) (Hausenblas & Downs, 2002b). The fit indices indicated adequate fit to the data ($\chi^2 = 351.9$ df $= 168$ $p < 0.0001$; CFI $= 0.938$; TLI $= 0.922$; RMSEA $= 0.049$ [0.042–0.056]; Cfit $= 0.590$; SRMR $= 0.052$). Factor loadings ranged between 0.45 and 0.88 and are presented in Table 4. However, the inspection of modification indices revealed that item 9 ("*I exercise when injured*") was a complex item, because it had salient cross-loadings on four other factors. Eliminating this item improved the model fit ($\chi^2 = 273.273$ df $= 149$ $p < 0.0001$; CFI $= 0.957$; TLI $= 0.945$; RMSEA $= 0.043$ [0.035–0.051]; Cfit $= 0.936$; SRMR $= 0.036$). Although this latter version of the measurement model provided better fit to the data, the original version was kept for the sake of comparability with other studies. Factor loadings and internal consistencies are presented in Table 1. The range of internal consistencies (Cronbach $\alpha$) of the subscales is between 0.62 and 0.88 in this sample.

### *Concurrent validity of the Exercise Addiction Inventory (EAI)*

Confirmatory factor analysis was performed to assess the concurrent validity of EAI using the EDS in the model description. The solution presented an adequate fit to the data ($\chi^2 = 651.724$ df $= 291$, $p < 0.0001$; CFI $= 0.908$; TLI $= 0.897$; RMSEA $= 0.052$ [0.046–0.057]; Cfit $= 0.306$; SRMR $= 0.055$). The correlation between the two measures was high ($r = 0.79$) supporting the convergent validity of both scales. The correlations among EAI and the subscales of EDS are presented in Table 2.

### *Prevalence of exercise addiction*

Based on the original classification systems of EDS and EAI, the prevalence data were assessed and their confidence intervals (95%) of asymptomatic, nondependent-symptomatic and at risk from exercise dependence groups for both measures in exercising population and in the general population as well. According to the EDS, 38.1% [33.7–42.6] of exercisers (6.2% [5.4–7.2] of the total sample) could be characterized as *nondependent-symptomatic exercisers*. According to the EAI, 61.0% [56.5–65.4] (10.1% [9.0–11.3] of the total

**Table 1**
Factor loadings and internal consistencies of Exercise Dependence Scale-21 and Exercise Addiction Inventory ($N = 474$).

| Item with the original numbering | Withdrawal | Continuance | Tolerance | Lack of control | Reductions | Time | Intention | EAI |
|---|---|---|---|---|---|---|---|---|
| *Exercise Dependence Scale-21** | | | | | | | | |
| 15. I exercise to avoid feeling tense. | 0.80 | | | | | | | |
| 8. I exercise to avoid feeling anxious. | 0.78 | | | | | | | |
| 1. I exercise to avoid feeling irritable | 0.71 | | | | | | | |
| 2. I exercise despite recurring physical problems | | 0.73 | | | | | | |
| 9. I exercise when injured | | 0.45 | | | | | | |
| 16. I exercise despite persistent physical problems | | 0.84 | | | | | | |
| 3.I continually increase my exercise intensity to achieve the desired effects/benefits | | | 0.76 | | | | | |
| 10. I continually increase my exercise frequency to achieve the desired effects/benefits | | | 0.88 | | | | | |
| 17. I continually increase my exercise duration to achieve the desired effects/benefits.. | | | 0.88 | | | | | |
| 4. I am unable to reduce how long I exercise | | | | 0.62 | | | | |
| 11. I am unable to reduce how often I exercise | | | | 0.73 | | | | |
| 18. I am unable to reduce how intense I exercise | | | | 0.77 | | | | |
| 5. I would rather exercise than spend time with family/friends | | | | | 0.57 | | | |
| 12. I think about exercise when I should be concentrating on school/work | | | | | 0.79 | | | |
| 19. I choose to exercise so that I can get out of spending time with family/friends | | | | | 0.61 | | | |
| 6. I spend a lot of time exercising | | | | | | 0.72 | | |
| 13. I spend most of my free time exercising | | | | | | 0.81 | | |
| 20. A great deal of my time is spent exercising | | | | | | 0.77 | | |
| 7. I exercise longer than I intend | | | | | | | 0.82 | |
| 14. I exercise longer than I expect | | | | | | | 0.84 | |
| 21. I exercise longer than I plan | | | | | | | 0.86 | |
| *Exercise Addiction Inventory (EAI)*** | | | | | | | | |
| 1. Exercise is the most important thing in my life | | | | | | | | 0.48 |
| 2. Conflicts have arisen between me and my family and/or my partner about the amount of exercise I do | | | | | | | | 0.38 |
| 3. I use exercise as a way of changing my mood | | | | | | | | 0.55 |
| 4. Over time I have increased the amount of exercise I do in a day | | | | | | | | 0.72 |
| 5. If I have to miss an exercise session I feel moody and irritable | | | | | | | | 0.66 |
| 6. If I cut down the amount of exercise I do, and then start again, I always end up exercising as often as I did before | | | | | | | | 0.48 |
| Factor determinacy | 0.91 | 0.90 | 0.95 | 0.92 | 0.88 | 0.93 | 0.94 | 0.86 |
| Mean | 6.36 | 5.80 | 7.29 | 6.12 | 4.05 | 6.22 | 5.35 | 14.17 |
| SD | 3.44 | 3.31 | 4.07 | 3.31 | 1.97 | 3.37 | 3.13 | 4.64 |
| Cronbach $\alpha$ | 0.80 | 0.68 | 0.87 | 0.62 | 0.67 | 0.80 | 0.88 | 0.72 |

*Note:* *: $N = 465$; **:$N = 458$. All loadings are significant at least $p < 0.001$.

sample) could be characterized as *nondependent-symptomatic exercisers*. The proportion of exercisers at-risk of dependence is 1.9% [1.0–3.7] among exercisers and 0.3% [0.1–0.6] in the general population as measured by the on EDS. Estimation based on the EAI resulted in slightly higher rates for being at-risk for dependence, that is 3.2% [2.0–5.3] in the case of regular exercisers and 0.5% [0.3–0.9] in the case of the total sample. EDS and EAI thus provided different estimations about the proportion of nondependent-symptomatic exercisers and exercisers at-risk of dependence that can be explained by the lack of empirically based cut-off scores for EAI.

*Assessment of the accuracy of the Exercise Addiction Inventory (EAI)*

Based on EDS as a "gold standard", the sensitivity, specificity, the positive and negative predictive values, and the accuracy for EAI were calculated at several cut-off points (see Table 3) in order to establish the most optimal thresholds. A cut-off at 13, as suggested by Terry et al. (2004), results in acceptable sensitivity (89% in this sample) with rather low specificity (53%), accuracy is only 63% at this point. At the next cut-off point at 14, accuracy is better (69%) with a still acceptable sensitivity (82%) and better specificity (59%). Accuracy reaches its best value at 16, but sensitivity decreases to 61% at this point. Lower cut-off points were also examined. The cut-off point 12 shows also a better accuracy than the original 13 do, with an excellent sensitivity (94%), but with an unacceptable specificity (44%).

To find the best cut-off point, ROC analyses were performed for all possible EAI cut-off points, with what could be sufficient to describe the full range of screening performance of the test. Fig. 1 presents the empirical ROC curve that provides the evidence for

**Table 2**
The correlations of subscales of Exercise Dependence Scale-21 and Exercise Addiction Inventory (EAI).

| | EDS-withdrawal | EDS-continuance | EDS-tolerance | EDS-lack of control | EDS-reductions | EDS-time | EDS-intention |
|---|---|---|---|---|---|---|---|
| EDS-withdrawal | | | | | | | |
| EDS-continuance | 0.34 | | | | | | |
| EDS-tolerance | 0.48 | 0.47 | | | | | |
| EDS-lack of control | 0.53 | 0.52 | 0.74 | | | | |
| EDS-reductions | 0.43 | 0.42 | 0.43 | 0.66 | | | |
| EDS-time | 0.54 | 0.53 | 0.75 | 0.82 | 0.67 | | |
| EDS-intention | 0.42 | 0.42 | 0.59 | 0.65 | 0.53 | 0.66 | |
| EAI | 0.46 | 0.46 | 0.64 | 0.71 | 0.58 | 0.72 | 0.57 |

*Note:* Correlations are estimated with the attenuation of measurement errors ($N = 466$). All correlations are significant at $p < 0.001$.

**Table 3**
Calculation of cut-off thresholds for AEI on the basis of the EDS-scale ($N = 457$).

| Cut-off AEI | TP (N) | TN (N) | FP (N) | FN (N) | Sens. (%) | Spec. (%) | PPV (%) | NPV (%) | Accuracy (%) |
|---|---|---|---|---|---|---|---|---|---|
| Differentiating the asymptomatic and the symptomatic/at risk cases | | | | | | | | | |
| 11 | 181 | 96 | 172 | 8 | 96 | 36 | 51 | 92 | 61 |
| 12 | 177 | 119 | 149 | 12 | 94 | 44 | 54 | 91 | 65 |
| 13 | 169 | 143 | 125 | 20 | 89 | 53 | 57 | 87 | 63 |
| 14 | 155 | 143 | 99 | 34 | 82 | 59 | 61 | 81 | 69 |
| 15 | 131 | 191 | 77 | 58 | 69 | 71 | 63 | 77 | 70 |
| 16 | 115 | 212 | 56 | 74 | 61 | 79 | 67 | 74 | 72 |
| 17 | 98 | 227 | 41 | 91 | 52 | 85 | 71 | 71 | 71 |
| 18 | 77 | 240 | 28 | 112 | 41 | 90 | 73 | 68 | 69 |
| Differentiating the symptomatic and at-risk cases | | | | | | | | | |
| 17 | 8 | 318 | 131 | 0 | 100 | 71 | 6 | 100 | 71 |
| 18 | 8 | 352 | 97 | 0 | 100 | 78 | 8 | 100 | 79 |
| 19 | 7 | 382 | 67 | 1 | 88 | 85 | 9 | 100 | 85 |
| 20 | 6 | 400 | 49 | 2 | 75 | 89 | 11 | 100 | 89 |
| 21 | 6 | 417 | 32 | 2 | 75 | 93 | 16 | 100 | 93 |
| 22 | 6 | 428 | 21 | 2 | 75 | 95 | 22 | 100 | 95 |
| 23 | 6 | 435 | 14 | 2 | 75 | 97 | 30 | 100 | 96 |
| 24 | 6 | 442 | 7 | 2 | 75 | 98 | 46 | 100 | 98 |
| 25 | 5 | 444 | 5 | 3 | 63 | 99 | 50 | 99 | 98 |

*Note:* True positive (TP), true negative (TN), false positive (FP) and false negative (FN); sens: sensitivity, spec.: specificity, sensitivity = TP/(TP + FN), specificity = TN/(TN + FP); positive predictive value (PPV) = TP/(TP + FP), negative predictive value (NPV) = TN/(TN + FN); accuracy = (TP + TN)/TOTAL.

the ability of the EAI to discriminate between participants who are classified asymptomatic (non-cases) and individuals who are classified nondependent symptomatic or at-risk by the EDS. The best performance of EAI in this discrimination was at an EAI observed test value of 14. The overall performance of the EAI was measured by the Area Under the Curve value (AUC). The AUC was 0.794 [0.754–0.835] with its 95% CI. Both its confidence interval and a statistical test under the nonparametric assumption confirmed that this area is significantly different from 0.50 ($p < 0.0001$).

To identify the threshold for the EAI to discriminate well between asymptomatic/non-dependent symptomatic and at-risk classified individuals another ROC analysis was performed. The best performance of EAI was at the test value of 24. The AUC was 0.957 [0.909–1.00] with its 95% CI. Statistical test (under the nonparametric assumption) confirmed that this area is significantly different from 0.50 ($p < 0.0001$). All coordinates of both ROC curves are available from the authors of this paper.

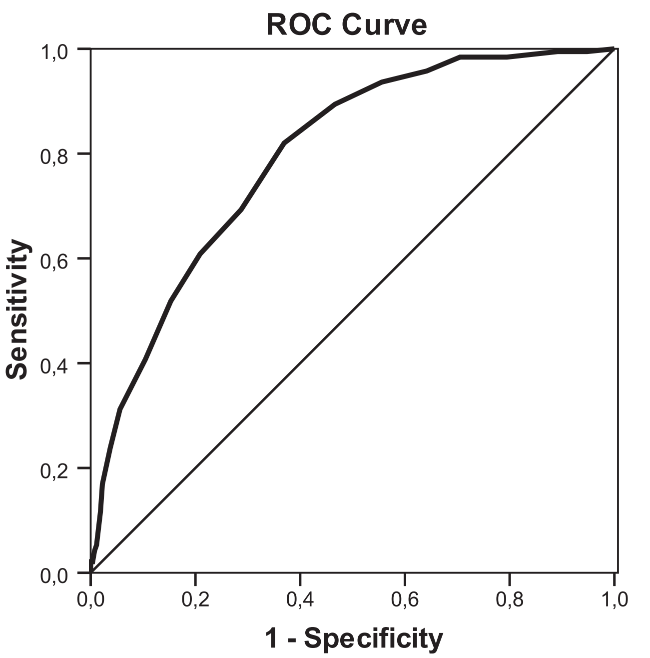


**Fig. 1.** Nonparametric ROC plot of EAI-HU at discriminating between asymptotic and non-dependent symptomatic/at-risk classified individuals.

Calculating the proportion of asymptomatic, non-dependent symptomatic, and at-risk classified individuals with new thresholds (0–13 = asymptomatic; 14–23 = symptomatic non-dependent; 24–30 = at risk from exercise dependence) resulted that 44.8% [40.4–49.4] of exercisers (7.4% [6.5–8.5%] of general population) could be characterized as asymptomatic, 52% [47.5–56.6] (8.6% [7.6–9.7%] of total sample) could be described as nondependent-symptomatic exercisers, and 3.2% [2.0–5.3%] (0.5% [0.3–0.9%] of total sample) could be classified as at risk from exercise dependence according to the new cut-off points of EAI (Table 4.).

The association of the exercise addiction with socioeconomic variables was tested. Using the three categories – asymptomatic, non-dependent symptomatic and at-risk – no significant associations with gender ($\chi^2 = 3.39$, $p > 0.05$), age ($F(2, 441) = 1.20$, $p > 0.05$), marital status (Fisher's Exact Test = 11.9, $p > 0.05$), education level (Fisher's Exact Test = 10.70, $p > 0.05$), deprivation level (Welch test $F(2, 34.86) = 1.44$, $p > 0.05$), or employment status (Fisher's Exact Test = 11.38, $p > 0.05$) were found.

## Discussion

In the present study, validation of two exercise addiction measures was carried out and cut-off points of EAI were defined using the EDS, a scale based on the 'gold standard' of DSM-IV psychoactive substance use dependence criteria. Furthermore, the study was the first ever national prevalence survey examining exercise addiction. As a consequence, the present study significantly adds to the knowledge base in the area. Original factor structures of both inventories were confirmed and the two measures, in line with the expectations, showed high correlation ($r = 0.79$). Based on the results of ROC analyses, raising cut-off points of EAI by one point appears to be reasonable in case of differentiating between nondependent symptomatic and asymptomatic persons. Perhaps more importantly the study is the first to assess the prevalence of exercise addiction on a national representative sample. Regarding previous estimates on the prevalence of exercise addiction the following problems were identified: (1) psychometric reliability of the applied measures was often uncertain, and (2) mostly ad hoc, convenient and/or inadequately defined samples were analysed.

The results presented here (using a nationally representative sample) now confirm the hypothesis suggested in earlier studies, that exercise addiction does not belong to the group of frequent disorders among general population (Sussman et al., 2011). On the basis of results obtained with the two questionnaires, 0.3–0.5% of population is involved seriously, which equates to 1.9%–3.2% of weekly regular exercisers. At the same time, these data do not contradict with the majority of previous studies that indicated much higher values among intensive exerciser populations.

The present study is the first national study ever to assess the prevalence of exercise addiction in a representative sample of participants of the target population and therefore there are no studies to compare the findings of this study to. This study provides primary benchmark data that subsequent national studies will need to be compared to. It also included the (first ever) comparative analysis of the psychometric properties of (arguably) the two most widely used screening instruments that assess exercise dependence/addiction. On these two assertions, the study's results are of high research value from both an exercise addiction screening accuracy standpoint and a public health and awareness standpoint. Based on

**Table 4**
Prevalence of asymptomatic, nondependent-symptomatic and at-risk for dependence populations.

| | In the general population | | | Among exercisers[a] | | |
|---|---|---|---|---|---|---|
| | EDS | EAI original cut-off | EAI modified cut-off | EDS | EAI original cut-off | EAI modified cut-off |
| Asymptomatic | 10.0% [8.9–11.2] | 5.9% [5.1–6.9] | 7.4% [6.5–8.5] | 60% [55.3–64.4] | 35.8% [31.5–40.4] | 44,8% [40.4–49.4] |
| Nondependent-symptomatic | 6.2% [5.4–7.2] | 10.1% [9.0–11.3] | 8.6% [7.6–9.7%] | 38.1% [33.7–42.6] | 61.0% [56.5–65.4] | 52% [47.5–56.6] |
| At-risk for dependence | 0.3% [0.1–0.6] | 0.5% [0.3–0.9] | | 1.9% [1.0–3.7] | 3.2% [2.0–5.3] | |

[a] Exercisers were defined as doing some kind of exercise at least on a weekly basis. EDS: $N = 441$; EAI: $N = 447$. Cases with missing data were excluded in the present table.

the results of this study, it would appear that both tools examined (i.e., EAI and EDS) can reliably be applied in the future for both scientific research in the exercise addiction field, and as a screening instrument in non-research settings. For instance, the short, 6-item EAI could be used as a screening instrument in empirical surveys as a way of combating questionnaire fatigue. It could also be used as a 'quick and easy' tool that can be used by health practitioners (such as GPs with their patients) in screening for exercise addiction. The EDS would also suitable for acquiring a more detailed and greater empirical insight to the problem in future studies.

However the study is not without limitations. Owing to the sampling method, it was financially unfeasible to use observational data on physical activity and/or face-to-face clinical interviewing, and therefore had to base the subsequent analysis solely on self-reports. Self-report data is also prone to the weaknesses of survey methodologies more generally including factors such as recall bias and social desirability. Another limitation of this study was the cross-sectional nature of the present data, therefore the causality inferences are limited, although further research may identify trends in exercise behaviours and provide models to determine the changes in exercise addiction. Another important question is the generalizability of these results to other countries. However, this question cannot be answered in a reliable way. Though the prevalence of regular exercise is lower in Hungary than in most of the other countries of the European Union (TNS Opinion & Social, 2010), this result, in and of itself, does not necessarily mean that prevalence of excessive exercise is lower as well. It is also possible that though the prevalence of regular exercise is lower than in other countries, prevalence of exercise addiction among the exercisers is higher. Thus careful consideration is needed concerning generalization elsewhere.

Given that earlier studies have been carried out on very different samples and prevalence rates were highly variable (see Berczik et al., 2012), comparison of these with the present results is very difficult. However, samples in previous studies that most resemble the present study's sample gave similar results. Using the EDS in the USA, Hausenblas and Downs (2002c) found that about 2.5% of the exercising population may be affected by exercise addiction. These data fall in the confidence interval (1.0–3.7%) of our results in respect of the same measure. In another study, using the EAI in Britain, Griffiths et al. (2005) found that 3% of undergraduate students were at risk of exercise addiction which is again very close to our finding of 3.2% [2.0–5.3]. Nevertheless, it is a task for the future to carry out similar normal population surveys on representative national samples in other countries of the world. This would make national comparative analysis possible. One significant result of the present study is that it confirmed that the available questionnaires are methodologically suitable and might provide a valid base for executing such studies.

Conclusively, it can be stated that while optimal regular exercising is a key component of preserving and improving physical and mental health, in case of a small proportion of the population, excessive exercise can generate significant problems. Identification of this population for the sake of successful prevention or possibly other interventions is indispensable. However, for this aim such measures are necessary in being able to validly estimate the severity of these problems. According to the in-depth results presented here, both the EDS and EAI are adequate screening solutions to assessing exercise dependence/addiction within target populations. While the seven-factor EDS might give a more complex picture on the problem, the short, 6-item EAI has the added advantage of providing anyone who uses the instrument with an estimation of problems with exercise very quickly. Nevertheless, clinical validation of these assessment tools needs to be further targeted and scrutinized by future research.

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