

## NATURE-BASED ADVENTURE INTERVENTIONS

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### 2 **The effect of nature-based adventure interventions on depression: A systematic review**

3

#### **Abstract**

4 We conducted a systematic review to synthesize evidence of the effect of nature-based  
5 adventure (NBA) interventions on depressive symptoms. Our search was conducted in April  
6 2021 and utilized the following databases: MEDLINE (PubMed), PsycINFO, SPORTDiscus,  
7 CINAHL, Google Scholar, and Clinicaltrials.gov. Forty-two studies ( $n = 2689$  participants)  
8 with different designs, published between 1979 and 2021, were included. Collectively, results  
9 suggest highly variable effects of NBA interventions on depressive symptoms, ranging from  
10 reductions in mean depression scores of up to 64% to increases in means scores of up to 18%.  
11 Patient adherence to interventions was also variable, and serious adverse events (e.g., leg  
12 fractures) did occur. Despite variability across studies, research generally showed that  
13 mountain-based and surfing interventions, coupled with other forms of care, may substantially  
14 reduce adults' depressive symptoms more than usual care alone or no intervention,  
15 highlighting the potential benefits of some NBA activities for individuals experiencing  
16 depressive symptoms.

17 *Keywords:* adventure therapy, mental health, nature-based therapy, outdoor recreation,  
18 wilderness therapy

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20 **The Effect of Nature-Based Adventure Interventions on Depression: A Systematic**21 **Review**

22 Depression is one of the most important global health challenges (Cipriani et al.,  
23 2018). Over 300 million people in the world live with this psychological disorder, which can  
24 harm many dimensions of people's lives including social relationships and professional  
25 achievements (World Health Organization, 2017). Depression became an even greater  
26 concern during the COVID-19 pandemic, with risk factors such as social isolation and  
27 hopelessness on the rise (Rodríguez-Rey et al., 2020; Schiller et al., 2022). The use of drugs  
28 prescribed by physicians and psychological therapy are two of the most well-known and  
29 recommended treatments for depression (Lopresti, 2019). These pharmaceutical and  
30 psychological strategies have been proven effective for many people, but research suggests  
31 that combining mainstream treatments with complementary activities may improve depressive  
32 symptoms more than mainstream treatments alone (Lopresti, 2019; McCormack &  
33 Korownyk, 2018). Potential complementary activities that might prove valuable include  
34 physical exercise (Catalan-Matamoros et al., 2016), changes in diet (Berk & Jacka, 2019), and  
35 contact with nature (Rosa et al., 2021). Nature-based adventure (NBA) interventions often  
36 combine several of these activities, including prolonged contact with nature, and stand out as  
37 a treatment that can have a particularly positive effect on people's depressive symptoms  
38 (Bowen & Neill, 2013; Sturm et al., 2012; Wall, 1993).

39 NBA interventions consist of the promotion of one or more adventure-oriented  
40 activities that occur in a natural setting – an environment that has a notable presence of  
41 soil/rock (e.g., mountains), vegetation (e.g., trees), and/or water, and that is not greatly altered  
42 by humans (Wohlwill, 1983). Adventure activities are often characterized by the uncertain  
43 nature of their outcomes, the skill and training required to conduct them, and their novelty.

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44 These activities do not need to be physically strenuous but should involve a reasonable  
45 amount of risk (Bowen & Neill, 2013; Houge Mackenzie & Goodnow, 2021). For instance,  
46 camping in a wilderness area may not require high-intensity physical activity but often  
47 involves the risk of getting lost and/or being hurt by an animal (Cave, 1979; Putra, 2016).  
48 Activities such as camping, backpacking, surfing, rock climbing, and skiing are normally  
49 classified as adventurous (Bettmann et al., 2016; Bowen & Neill, 2013). As a counter-  
50 example, forest bathing (Shirin-yoku), a healing practice in which individuals immerse  
51 themselves in nature while mindfully paying attention to their senses, is not necessarily an  
52 adventure activity since this practice can be performed in virtually risk-free environments  
53 such as urban-proximate recreational forests (Harper et al., 2021; Rosa et al., 2021). Thus,  
54 although forest-bathing is nature-based, it is not necessarily NBA. Likewise, other nature-  
55 based health promotion strategies such as meditating in a botanical garden (Djernis et al.,  
56 2019) or spending time in urban greenspace (Soga et al., 2017) may be beneficial but are not  
57 considered NBA interventions.

58         Conceptually, NBA interventions may encompass both wilderness therapy (i.e.,  
59 therapy done in wilderness environments) and nature-based adventure (i.e., adventure  
60 activities done in any natural setting) (Bowen & Neill, 2013; Fernee et al., 2017; Houge  
61 Mackenzie & Goodnow, 2021). Thus, NBA interventions need not be confined to wilderness  
62 (e.g., a beach close to an urban area might suffice), and they may or may not include any form  
63 of conventional therapy such as psychotherapy (Bowen & Neill, 2013; Fernee et al., 2017;  
64 Houge Mackenzie & Goodnow, 2021). In the present study, we consider therapy in a broad  
65 sense as any activity provided to improve a person's health (Rosa et al., 2021). Therapeutical  
66 activities may include, for instance, psychotherapy, group work, and physical exercises – all  
67 of which may be integrated with NBA (Bowen & Neill, 2013; Fernee et al., 2017; Houge  
68 Mackenzie & Goodnow, 2021; Rosa et al., 2021).

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69           Several researchers have suggested that NBA interventions can improve symptoms of  
70 depression such as individuals' inability to feel pleasure (Hyer et al., 1996), sad mood (Wall,  
71 1993), feeling bad about oneself (Fernee et al., 2017), hopelessness (Sturm et al., 2012), and  
72 difficulty in concentrating (Krebs, 2013), and sleep problems (Shin et al., 2012). Although no  
73 singular theory explains the possible effect of NBA interventions on depressive symptoms,  
74 the improvement of symptoms is in line with Attention Restoration Theory (ART, Crossan &  
75 Salmoni, 2021; Kaplan, 1995; Ohly et al., 2016) and Stress Recovery Theory (SRT, Berto,  
76 2014; Jiang et al., 2021; Ulrich et al., 1991). These theories suggest that positive experiences  
77 in nature can reduce stress and anxiety, be pleasurable, and improve mood and concentration.  
78 This aligns with the view that many natural settings (e.g., beaches, forests, and mountains)  
79 have characteristics that favor stress recovery and attention restoration (Kaplan, 1995;  
80 Moreton et al., 2021; Ulrich et al., 1991). For example, Moreton et al. (2021) argue that water  
81 immersion during surfing can reduce physiological inflammation, which is a predictor of  
82 depression. Rosa et al. (2021) found evidence that therapeutic activities conducted in forests  
83 may improve symptoms of depression more than carrying out the same activities at a hospital  
84 setting or in an urban area.

85           In addition to ART and SRT, frameworks that describe the health benefits of NBA  
86 activities can also help to explain the impact of NBA interventions on depressive symptoms  
87 (Fernee et al., 2017; Houge Mackenzie et al., 2021; Russell & Farnum, 2004). For example,  
88 the Wilderness Therapy Clinical Model argues that wilderness therapy can enhance people's  
89 self-confidence, resilience, and positive social interactions (Fernee et al., 2017). Improvement  
90 of depressive symptoms might also be achieved through the various forms of moderate to  
91 vigorous physical activity that is an inherent part of NBA activities such as rock-climbing,  
92 surfing, and backpacking (Catalan-Matamoros et al., 2016; Moreton et al., 2021; Rebar et al.,  
93 2015).

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94           Despite the opportunities that NBA interventions offer for improving depressive  
95 symptoms, some potential drawbacks also exist. Participants of NBA interventions can feel  
96 alone after the experiences, which usually involve intense social interactions (Muller, 1971).  
97 Other negative feelings may emerge after NBA interventions too. Gabrielsen et al. (2019)  
98 found that some participants expressed sadness and anger once the NBA intervention they  
99 engaged in concluded. Moreover, when involved in NBA interventions, participants can feel  
100 emotionally challenged and frustrated (Amrhein, 2016; Fernee et al., 2017). These emotional  
101 challenges may include being away from home, no interaction with family members for  
102 extended periods, a lack of modern comforts, and confronting uncertainty and risk (Williams,  
103 2009). When such stressors are present, depressive symptoms may intensify.

104           Although the use of NBA interventions as a complementary or alternative intervention  
105 to reduce depressive symptoms is growing, the range and variability of findings from these  
106 interventions remain unknown. Furthermore, many NBA interventions may be combined with  
107 other types of interventions (e.g., individual counseling and group discussion), generating  
108 study designs that rarely enable researchers to separate the effects of the NBA activities from  
109 that of the complementary interventions provided. Given this uncertainty and the need for  
110 additional clarity regarding the benefits of NBA interventions, we conducted the first  
111 systematic review to summarize the possible effect of NBA interventions on depressive  
112 symptoms. During the review process, we also collected information related to patient  
113 adherence (i.e., the number of participants who dropped out from the interventions) and the  
114 number of adverse events experienced during the interventions. Considering there is mixed  
115 evidence in the literature regarding the potentially beneficial or detrimental effects of NBA on  
116 depressive symptoms, we did not develop any hypothesis for this systematic review. This lack  
117 of a hypothesis is compatible with the exploratory approach of our systematic review  
118 (Higgins et al., 2019).

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### Method

121 The methods we employed in this systematic review are explained in detail in our  
122 registered protocol (Supplementary File 1). The review is reported following the Preferred  
123 Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et  
124 al., 2021). Differences between the protocol and our systematic review are described in  
125 Supplementary File 2. The references and data from studies included in this systematic review  
126 are included in Supplementary File 3. Below, we summarize the guiding question of this  
127 review, the eligibility criteria, the search strategy, the procedure used for including and  
128 excluding studies, data extraction, risk of bias assessment, and data synthesis.

### 129 Systematic Review Question

130 What is the effect of NBA interventions on depressive symptoms as compared to  
131 alternative interventions (or no intervention)?

### 132 Criteria to Include Primary Studies

133 The criteria for inclusion in our review are detailed in Table 1. Essentially, we  
134 included studies focused on any population (regardless of age and health status) that evaluated  
135 the effects of some form of NBA intervention on depressive symptoms. When reading the  
136 description of the intervention by the studies identified through the search strategy, we  
137 evaluated whether the primary activity is usually classified as adventurous (e.g., surfing,  
138 rappelling, skiing) and whether it entails a substantial amount of risk. We excluded studies  
139 with nature-based interventions that did not entail considerable risk, such as walking at an  
140 urban-proximate beach or in a city park. Importantly, adventure activities had to occur in a  
141 natural setting, even if that setting was not a wilderness area. Many studies were excluded  
142 because they did not describe the setting where the intervention took place in enough detail,  
143 hindering our judgment of whether the intervention occurred in a natural environment. To

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144 illustrate, we excluded studies where the intervention was organized in a swimming pool. We  
145 did not exclude studies that provided other interventions (co-interventions) associated with  
146 the NBA activities. We also did not exclude studies based on language and included both  
147 published (i.e., peer-reviewed papers) and unpublished studies (e.g., Ph.D. dissertations).

148 <Please insert Table 1 about here>

149 To generate a broad synthesis of the possible effect of NBA interventions on  
150 depressive symptoms, we included randomized studies, non-randomized controlled trials  
151 (NRCTs), and studies without a comparison group (i.e., one-group studies). Because any  
152 person can experience depressive symptomatology to a certain degree (e.g., sleep or  
153 concentration problems), we did not limit this review to studies that included people  
154 diagnosed with depression. Moreover, we included studies independent of how well they  
155 reported their findings (Higgins et al., 2019). This inclusive approach allowed us to gather  
156 comprehensive information on how NBA has been used in existing research.

### 157 **Search Strategy**

158 On April 20 or 21 of 2021, the first author searched the databases MEDLINE  
159 (PubMed), PsycINFO, SPORTDiscus, CINAHL, Google Scholar, and Clinicaltrials.gov, from  
160 inception to the date of the search. Our exact search strategy is described in our registered  
161 protocol (Supplementary File 1). To favor a more complete coverage, we also checked the  
162 references of included studies, previous systematic reviews on related topics, and studies  
163 relevant to the review that we as authors were aware of. Additionally, we emailed experts on  
164 the topic who might provide access to additional studies. This comprehensive search strategy  
165 resulted in the identification of many unpublished studies. We were able to find and download  
166 many unpublished studies by accessing the ProQuest database, searching for content on the  
167 Internet, and contacting researchers by email.

### 168 **Study Selection, Data Extraction, and Risk of Bias Assessment**

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169           The first author performed title and abstract screening, the decision of including or  
170 excluding studies based on full-text, data extraction, and risk of bias assessment. Another  
171 researcher checked the inclusion/exclusion decision of all studies assessed in full text. This  
172 other researcher also checked the data extracted by the first author and the risk of bias  
173 assessment for randomized studies. Specifically, the second researcher read through the  
174 decisions made by the first researcher and approved/disapproved them. Few disagreements  
175 emerged, and those that did were rapidly resolved through discussion. All variables that  
176 formed the basis for the extracted dataset are described in our registered protocol  
177 (Supplementary File 1). Examples of variables of interest include the depression score at  
178 baseline and after the intervention (a proxy for intervention efficacy), the number of dropouts  
179 (a proxy for patient adherence), and adverse events (a proxy for risk). The risk of bias of  
180 randomized studies was assessed with the RoB 2 tool (Sterne et al., 2019), and the risk of bias  
181 for studies with other types of designs was assessed with ROBINS-I (Sterne, Higgins, et al.,  
182 2016). These are the tools recommended by Cochrane (Higgins et al., 2019).

### 183 **Data Synthesis**

184           Following the recommendations of Higgins et al. (2019), we summarized the studies  
185 according to their design and focused primarily on randomized studies. Thus, in the main text,  
186 tables, and figures, we included information summarizing randomized studies. Other types of  
187 studies (e.g., non-randomized controlled trials and one-group studies) are briefly summarized  
188 in the text, and tables and figures synthesizing information from studies with these different  
189 designs are reported in Supplementary File 2.

190           To estimate the effect of NBA interventions on depressive symptoms, we extracted  
191 data from the pre-test closest to the start of the intervention and the post-test closest to the end  
192 of the intervention. When studies used more than one depression outcome measure, we  
193 selected just one measure based on pre-specified criteria (see “Dealing with Multiple Effect



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194 Estimates” in Supplementary File 1). Although depression outcome measures varied, we were  
195 able to calculate the percentage of change in depressive symptoms from baseline to post-  
196 intervention and the standardized mean change (as described by Morris, 2008) in the majority  
197 of studies. The percentage of change is more appropriate than the difference between groups  
198 following treatment when group scores differ substantially at baseline (Vickers, 2001). We  
199 calculated standardized mean change by dividing the change score from baseline to post-  
200 intervention by the standard deviation at baseline (Morris, 2008).

201 Another outcome of interest was the number of participants who demonstrated  
202 substantial improvement following the intervention. We operationalized response to the  
203 intervention as a  $\geq 50\%$  reduction in depressive symptoms from baseline (Riedel et al.,  
204 2010). Research shows that a  $\geq 50\%$  reduction is a good proxy for clinically relevant  
205 improvement in depression as assessed by three depression scales: Hamilton Depression  
206 Rating Scale (HDRS), Beck Depression Inventory (BDI), and Montgomery Asberg  
207 Depression Rating Scale (MADRS, Riedel et al., 2010). In line with this, we calculated the  
208 number of participants reporting a  $\geq 50\%$  reduction in depressive symptoms when the studies  
209 used one of these three scales. This number was calculated using the formula provided by  
210 Furukawa et al. (2005). For all studies with available data, we report the number of  
211 participants who dropped out and the adverse events (e.g., injury) that occurred. When  
212 feasible, we calculated risk ratios for dichotomous outcomes because these are easier to  
213 understand than odds ratios (Higgins et al., 2019).

214 After tabulating all studies’ characteristics, we concluded that a statistical combination  
215 of effect estimates (i.e., meta-analysis) across all studies included in the systematic review  
216 was not the best way to summarize findings. The reason for this is that the studies were  
217 different in many key ways such as participants’ characteristics, types of interventions (e.g.,  
218 specific adventure activities provided), and comparison groups. However, we deemed it

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219 appropriate to report evidence from a smaller subset of parallel-group randomized controlled  
220 trials (RCTs). We used a forest plot, as recommended by Higgins et al. (2019), to allow  
221 readers to visualize effect estimates and corresponding variability from each study. These  
222 estimates were standardized mean differences (Hedges'g) between the post-intervention  
223 depression mean score of the NBA group and the comparison group. Post-intervention  
224 depression scores were considered in this forest plot because the RCTs did not report the  
225 standard deviation of the change scores (i.e., change from the pre to post-intervention). Due to  
226 the variability in the study's characteristics, we did not assess differences in effect estimates  
227 between published (i.e., journal articles) and non-published studies, since possible differences  
228 might be due to factors other than publication bias. To facilitate interpretation of the findings  
229 of the studies included in this systematic review, we report estimates of effects and, when  
230 feasible, 95% confidence intervals (CI) for these estimates. Hedges'g and risk ratios were  
231 calculated using RevMan (*Review Manager (RevMan) [Computer Program]*, 2020), and  
232 figures illustrating the risk of bias of primary studies were created using robvis (McGuinness,  
233 2019).

234

### Results

235 Our database searches produced 440 records, of which 98 were deemed sufficiently  
236 relevant to assess at full-text. From these 98 studies, 26 were considered eligible for our  
237 review (Figure 1). An example of a study excluded at full-text assessment is Kleinstäuber et  
238 al. (2017). This study was excluded because even though an adventure activity was provided  
239 (e.g., rock climbing), the activity did not take place in a natural setting. Sixteen additional  
240 relevant studies were identified in previous systematic reviews focused on related topics (e.g.,  
241 Bowen & Neill, 2013), in the reference lists from our included studies, or among the studies  
242 our team of authors was already familiar with.

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243 Overall, 42 studies (with  $n = 2689$ , ranging from two to 335 participants per study)  
244 were included in this systematic review. These studies took place in 12 different countries.  
245 Most studies were conducted in the United States of America (22 studies) and Australia (7  
246 studies). No study was conducted in Africa or Latin America. Seventeen of the studies were  
247 not published in scientific journals. These included 11 dissertations, three theses, two  
248 technical reports, and a symposium paper. From the 42 studies included studies, the oldest  
249 was reported in 1979 and the newest in 2021. Most studies (57%) were reported in the last 10  
250 years (from 2012 to 2021). Nineteen studies were conducted with children and adolescents  
251 and 23 with adults. Participants in these studies were quite diverse, including people with or  
252 judged at risk of having mental health problems, people with diseases like cancer and  
253 diabetes, and both K-12 and college students. Only one study focused on older adults  
254 (Finkenzeller et al., 2011).

255 NBA interventions involved a wide range of activities such as hiking, camping,  
256 surfing, canoeing, kayaking, rafting, sailing, ropes courses, caving, rock climbing, abseiling,  
257 skiing, and mountain biking. Hiking and camping were among the most popular activities,  
258 whereas only a few studies examined interventions involving skiing, kayaking, and mountain  
259 biking. The majority of studies included interventions with more than one NBA activity (e.g.,  
260 hiking plus camping). There was also a high variability in the length, frequency, and duration  
261 of the interventions. Intervention length varied from one day to one year, with most studies  
262 considering a time length shorter than one month. The frequency of NBA interventions  
263 provided to participants ranged from every day to once a week. The duration of the NBA  
264 activities ranged from 15 minutes to up to 20 hours, though most studies did not report this  
265 information. NBA activities were commonly combined with other interventions such as more  
266 conventional care including pharmaceutical and psychological therapy. Diversity was also  
267 present in the comparison intervention approaches used across different studies, including no

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268 intervention, the inclusion of a waiting list, participants engaging in usual care, participation  
269 in non-adventure leisure activities, and participation in another type of NBA intervention.  
270 Twenty-two different measures were used to assess depressive symptoms, including the Beck  
271 Depression Inventory and the Center for Epidemiologic Studies Depression scale for children.  
272 The settings where NBA interventions took place varied from beaches close to cities to  
273 pristine wilderness areas. Regarding study design, we included eight parallel-group RCTs,  
274 one randomized crossover, eight NRCTs, and 25 one-group studies.

### 275 **Summary of Intervention Effects on Depressive Symptoms**

276         Considering all studies, change in depressive symptoms from pre to post-NBA  
277 interventions varied from a 64% reduction in participants' mean depression score to an 18%  
278 increase. Standardized mean change varied from -3.45 to 0.58. The proportion of participants  
279 who improved  $\geq 50\%$  from pre to post NBA intervention varied from 6% to 63%. The  
280 proportion of participants who dropped out from NBA interventions ranged from zero to 35%.  
281 Reasons for dropping out included health problems not associated with the intervention,  
282 adverse events that occurred during the intervention, lack of interest, family responsibilities,  
283 difficulty interacting with other people, scheduling problems, change of residence, and other  
284 commitments like school and work. Adverse events that authors reported occurring during  
285 NBA interventions included leg fracture, knee pain, falls, cut in the leg, getting lost, having a  
286 thumb broken, twisted ankle, frostbitten feet, illness, emotional problems, arm and shoulder  
287 pain, and being stung by stinging nettles.

288         To facilitate comparisons of findings among specific NBA activities, we made an  
289 exploratory effort to summarize the results of studies that provided similar NBA activities.  
290 However, only a few of the included studies had a specific NBA activity as the main  
291 intervention and, within these, variability was high regarding participants' and interventions'  
292 characteristics (e.g., length). Taking surfing as an example, we found five studies that used

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293 surfing as the only NBA activity in their intervention (Table 1 in Supplementary File 2). To  
294 illustrate the degree of variability across studies using surfing as the main NBA activity, the  
295 length of surfing interventions varied from one week to more than five months and from daily  
296 4-hour sessions to a once-a-week session of 15 to 20 minutes surfing. Change in depressive  
297 symptoms from pre to post-surfing interventions varied from a 41% reduction in participants'  
298 mean depression score to a 7% increase. Standardized mean change ranged from -3.45 to  
299 0.10. Only two studies reported the necessary data to calculate the rate of participants who  
300 had a  $\geq 50\%$  improvement in depressive symptoms from pre to post-surfing interventions.  
301 This proportion was 26% in Crawford (2016) and 33% in Amrhein (2016). The proportion of  
302 participants who dropped out from surfing interventions ranged from zero to 34%. No  
303 information about adverse events was reported by these studies.

304       As another example, we identified nine studies that provided hiking and/or camping as  
305 the main NBA activity (Table 2 in Supplementary File 2). Considering these studies, we  
306 found that changes in depressive symptoms from pre to post-intervention varied from a 59%  
307 reduction in participants' mean depression score to a 6% increase. Standardized mean change  
308 ranged from -1.18 to 0.12. Similar to surfing studies, only two studies reported the necessary  
309 data to calculate the proportion of participants who had a  $\geq 50\%$  improvement in depressive  
310 symptoms from pre to post-intervention. This was 47% in Sturm et al. (2012) and 63% in  
311 Wall (1993). The proportion of participants who dropped out from hiking and/or camping  
312 interventions varied from 3% to 20%. Concerning adverse events, only Wall (1993) reported  
313 that some participants withdraw due to illness and/or emotional problems.

314       While keeping this variability in mind, in the next sections we critically synthesize  
315 studies' findings according to study design, as recommended by Higgins et al. (2019). We  
316 first focus on a forest plot with effect estimates from randomized controlled trials (RCTs).  
317 Following, we present the results from the only randomized crossover trial included in this

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318 systematic review. Then, we briefly synthesize key results from studies with other types of  
319 designs.

### 320 **Characteristics and Results from Parallel-Group Randomized Controlled Trials (RCTs)**

321 Eight RCTs (with  $n = 681$ , ranging from 33 to 228 participants per study) met our  
322 eligibility criteria (Table 2). The oldest RCT was reported in 1999 and the newest in 2021.  
323 Five RCTs were conducted with children or adolescents and three with adults, and the studies  
324 spanned seven different countries. None of the randomized studies were conducted in Africa  
325 or Latin America. NBA activities provided by the RCTs included camping, hiking, canoeing,  
326 paddle boating, ropes course, rock climbing, surfing, skiing, and sailing. Intervention length  
327 varied from two days to one year, frequency from daily to weekly, and session duration  
328 ranged from one hour to up to four hours (Table 3). NBA interventions were not the only  
329 focus of all RCTs. For example, mountain climbing was just an element of the intervention  
330 reported by Shin et al. (2012), which also involved meditation and counseling. Only two of  
331 the RCTs did not report any kind of co-intervention. The NBA interventions (as single  
332 interventions or in combination with co-interventions) were compared to no intervention,  
333 waiting-list, and non-adventure leisure activities. Seven different measures of depression were  
334 utilized in these eight studies. The most frequently used measure was the Center for  
335 Epidemiological Studies – Depression Scale, which was used in two studies. Information  
336 about the interventions in each RCT and results are summarized in Tables 3 and 4. The risk of  
337 bias assessment of each RCT is available in Figure 2. Seven RCTs were classified as high risk  
338 of bias and one as some concerns.

339 <Please, insert Table 2, 3, 4, and Figure 2 about here>

340 Considering standardized differences in post-intervention scores for RCT studies with  
341 children (Figure 3), two studies supported a greater reduction in depressive symptoms by the  
342 NBA intervention than the comparison intervention, two studies suggested a negligible

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343 improvement following NBA activities, and one study suggested an increase in depressive  
344 symptoms. Hedges'  $g$  ranged from 0.52 to -0.44. For the RCTs involving adults, the forest plot  
345 (Figure 3) suggested that the NBA intervention produced a greater reduction in depressive  
346 symptoms than the comparison intervention, with Hedges'  $g$  of -0.49 and -1.06. In the seven  
347 RCTs with usable data, the imprecision of the estimates – indicated by wide confidence  
348 intervals - was considerable. The one study (also with adults) that was not included in the  
349 forest plot (Finkenzeller et al., 2011), reported a  $\eta^2 = 0.01$  ( $p = .80$ ) for the comparison of  
350 groups' post-intervention scores, indicating the NBA group and the comparison had similar  
351 post-intervention depression scores after the intervention. Only Shin et al. (2012)'s RCT  
352 involving adults provided data to calculate the number of participants who had a  $\geq 50\%$   
353 reduction in depressive symptoms from pre to post-intervention. In this study, participants in  
354 the NBA group were almost three times as likely to experience such a reduction in their  
355 depressive symptoms than the no intervention group (risk ratio = 2.76 [1.54, 5.01]).

356

357 <Figure 3 about here>

358 Six of the RCTs reported the number of participants who dropped out from the NBA  
359 intervention. The drop-out proportion varied from zero to 33%. Reasons for dropping out  
360 included health problems not associated with the intervention, adverse events that occurred  
361 during the intervention, lack of interest, and change of residence. Only two RCTs reported  
362 whether adverse events occurred during the NBA intervention. One study reported no adverse  
363 events (Chung et al., 2021) and the other study, which provided guided skiing to older adults,  
364 reported two leg fractures, three participants with knee pain, and 17 participants suffering  
365 falls (Finkenzeller et al., 2011; Müller et al., 2011).

366 **Characteristics and Results from a Randomized Crossover Trial**

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367 We found only one crossover trial meeting our eligibility criteria (Table 2). This trial  
368 was conducted in Germany with adults at risk of committing suicide (Sturm et al., 2012). The  
369 first group of participants took part in 9 weeks of a mountain hiking program (i.e., NBA  
370 intervention), and then moved on to a 9-week non-intervention phase (Table 3). A second  
371 group followed the inverse procedure (i.e., non-intervention first, followed by hiking). The  
372 order in which participants received each intervention was determined using random numbers.  
373 During the intervention, participants in both groups continued with their usual treatments,  
374 such as psychotherapy and pharmacotherapy. Considering the combined mean depression  
375 scores of both groups, there was a greater reduction in depressive symptoms during the  
376 mountain hiking phase than during the non-intervention phase (Cohen's  $d = -1.38$ ).  
377 Participants were almost seven times as likely to have a  $\geq 50\%$  reduction in depressive  
378 symptoms after the mountain hiking phase than after the no intervention phase (risk ratio =  
379 6.67, [1.15, 38.60]). Three of the 20 participants dropped out due to complications after  
380 shoulder surgery (not related to the intervention), family responsibilities, or difficulty  
381 interacting with other people. Information about adverse events was not reported. This study  
382 was deemed as at high risk of bias due to lack of blinding and a possible carryover effect,  
383 where the effects of an intervention given in the first period persist into the second period  
384 (Higgins et al., 2021).

### 385 **Summary of Characteristics and Results from Non-randomized Controlled Trials** 386 **(NRCTs) and One-group Studies**

387 In this systematic review, we focus on the characteristics and findings of randomized  
388 studies. Nonetheless, to have a more comprehensive knowledge of the research utilizing  
389 NBA, we also included non-randomized studies. More specifically, we included eight NRCTs  
390 (with  $n = 1051$ , ranging from 37 to 335 participants per study) and 25 one-group studies (with  
391  $n = 940$ , ranging from two to 134 participants). In most NRCTs, the group engaging in NBA



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392 interventions experienced a reduction in the mean depression score from baseline to post-  
393 intervention. However, this reduction was generally lower than 10%, and some studies  
394 observed an increase in depressive symptoms after the NBA intervention (see Section 2.2. in  
395 Supplementary File 2).

396       Regarding the one-group studies, 23 of the 25 included studies found, on average, a  
397 reduction in depressive symptoms after the NBA intervention, and only one study found an  
398 increase in these symptoms. Moreover, in nine of these 23 studies, the reduction in depressive  
399 symptoms was  $\geq 25\%$ . It should be noted, however, that both the NRCTs and the one-group  
400 studies were deemed as at serious risk of bias (see Section 2.3. in Supplementary File 2).

### Discussion

402       Our systematic review included 42 studies that estimated the effect of NBA  
403 interventions on participants' depressive symptoms. Findings suggest that some NBA  
404 interventions may improve symptoms of depression in children, adolescents, and adults.  
405 Considering the direction of the estimates of NBA effects on depression, virtually all studies  
406 found an improvement in participants' depressive symptoms, and many of these reported  
407 improvement may be considered relevant.. For instance, nine one-group studies observed a  $\geq$   
408 25% reduction in participants' depressive symptoms after the NBA intervention, one  
409 randomized crossover trial found NBA participants were almost seven times as likely to have  
410 a  $\geq 50\%$  reduction in depressive symptoms compared to individuals not experiencing  
411 interventions, and a majority of RCTs reported general reductions in post-intervention  
412 depression scores for NBA participants – especially among adults (Figure 3).

413       Following Higgins et al. (2019), we focused our synthesis efforts on randomized  
414 studies. Considering the five randomized studies conducted with children, none of them found  
415 a large improvement in depressive symptoms after the NBA intervention (Figure 3).  
416 Moreover, we cannot discern the effect of NBA interventions from that of the co-

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417 interventions in the two randomized studies with youth which found some evidence that NBA  
418 may reduce depressive symptoms more than alternative interventions. Among the randomized  
419 studies conducted with adults, two of them suggest that nature-based adventure can promote a  
420 large reduction in adults' depressive symptoms as compared to usual care or no intervention  
421 (Shin et al., 2012; Sturm et al., 2012). For example, Shin et al. (2012) found that participants  
422 in the NBA group were almost three times as likely to experience a reduction  $\geq 50\%$  in their  
423 depressive symptoms than the group without intervention. The third study with adults  
424 (Finkenzeller et al., 2011) found no evidence that the NBA intervention (skiing) reduced older  
425 adults' depressive symptoms.

426         Our study's findings are generally in line with those of previous systematic reviews  
427 assessing the effect of adventure interventions on mental health (e.g., Bettmann et al., 2016;  
428 Bowen & Neill, 2013). For example, Bowen et al. (2013) combined 28 effect sizes from  
429 studies assessing the impact of adventure interventions on measures of depression,  
430 depression/anxiety, and mood. They found a Hedges'  $g$  of 0.37 [0.23, 0.51] and an  $I^2 = 81\%$ ,  
431 which was similar to the quantitative synthesis of the seven RCTs included in this systematic  
432 review (Figure 3, Hedges'  $g = -0.32$  [-0.63, -0.00],  $I^2 = 72\%$ ). Like our systematic review,  
433 Bowen et al.'s (2013) results suggest that the change in depressive symptoms after adventure  
434 activities is often small and varies substantially from one study to another. Nonetheless, our  
435 review offers more information since we report and interpret the results of each study  
436 individually, instead of focusing on the combined estimate from all studies. Hence, we noted  
437 that there is stronger evidence supporting NBA as an intervention to reduce the depressive  
438 symptoms of adults than the depressive symptoms of young people (Figure 3). Moreover, we  
439 observed that the benefits of NBA might depend on the types of activities provided. For  
440 example, whereas two randomized studies support mountain-based adventure activities as  
441 interventions to reduce adults' depressive symptoms (Shin et al., 2012; Sturm et al., 2012), no

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442 improvement was observed in a randomized study of skiing intervention (Finkenzeller et al.,  
443 2011). This skiing intervention was associated with leg fractures and falls, which may have  
444 prevented improvements in depressive symptoms.

445         Several potential mechanisms could explain why NBA interventions are effective.  
446 Research has shown that any type of nature exposure can produce restorative benefits that  
447 influence health outcomes (Keniger et al., 2013). The benefits of nature-based activities may  
448 be even more pronounced when they involve some degree of physical activity (such as NBA).  
449 Individuals who are physically active in nature often report reductions in stress and anxiety,  
450 and improvements in attention, mood, and sleep quality (Gladwell et al., 2013; Kaplan, 1995;  
451 Lackey et al., 2019; Moreton et al., 2021; Rebar et al., 2015; Rosa et al., 2021; Shin et al.,  
452 2012; Ulrich et al., 1991). Additional explanations for the positive effects of NBA on  
453 depression are that counseling and positive social interactions, often co-occurring during these  
454 NBA interventions, may improve symptoms like hopelessness and feeling bad about oneself  
455 (Fernee et al., 2017; Li et al., 2013; Sturm et al., 2012). Another plausible pathway linking  
456 NBA interventions to improved depression symptomatology is that confronting the challenges  
457 faced in NBA may enhance participants' self-confidence and resilience (Fernee et al., 2017).  
458 This enhanced sense of self-confidence and resilience may, in turn, lead to reductions in  
459 depressive symptoms.

460         Unfortunately, the design of most studies did not allow us to assess the unique or  
461 added benefits of NBA interventions relative to other treatments. Among the randomized  
462 studies, for example, seven of the nine studies reported some kind of co-intervention (Table  
463 3). Hence, in many studies, it was not possible to separate the effect of the NBA activity from  
464 that of other activities in which participants were involved. One exception was a randomized  
465 crossover trial with adults that found that NBA plus usual care promoted a greater reduction  
466 in depressive symptoms than usual care only (Sturm et al., 2012). Additionally, no study

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467 compared indoor adventure activities (e.g., indoor wall climbing) to adventure activities in  
468 outdoor settings (e.g., mountain climbing).

469         Despite the predominance of findings suggesting NBA can help alleviate depressive  
470 symptoms, four of the 42 included studies reported increases in participants' symptoms of  
471 depression after an intervention. These results suggest that different NBA interventions have  
472 different effects on participants' depressive symptoms. Effects may vary according to several  
473 factors including characteristics of the NBA provided (e.g., type of activity, length, frequency,  
474 and duration) and individual variables such as participants' motivation to engage in NBA. For  
475 example, Vissell (2004) assessed the change in depressive symptoms in children and  
476 adolescents engaging in three different NBA interventions: Sage Walk, Synergia Learning  
477 Ventures, and Catherine Freer Wilderness Therapy Expeditions. However, in just one of these  
478 interventions (i.e., Synergia Learning Ventures program) were 100% of people willing to  
479 participate. This intervention was the only that produced an average improvement in  
480 participants' mean depression score, underscoring the important influence of participants'  
481 motivation on intervention success.

482         Similarly, the percentage of participants who dropped out from interventions varied  
483 considerably from one study to another (from zero to 35%). This variability may be explained  
484 by the relationship between the intervention's characteristics (e.g., the intensity of adventure  
485 activities) and participants' preferences (e.g., some participants may dislike high-intensity  
486 activities). When an intervention's characteristics and participants' preferences match, the  
487 intervention may be more enjoyable. When they don't align, dropouts are more likely. Some  
488 participants may also drop out due to health problems related or not related to the intervention  
489 (Müller et al., 2011; Wall, 1993). Only seven included studies reported whether adverse  
490 events occurred or not during the intervention. These included serious adverse events like  
491 bone fractures, cut in the leg, twisted ankle, frostbitten feet, illness, and emotional problems.

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492 This underscores the point that adventure activities are not risk-free, and it highlights the  
493 importance of weighing the risk-benefit ratio of NBA interventions. We encourage future  
494 studies of NBA interventions to report more information regarding adverse events, which  
495 would help participants, intervention providers, and researchers to assess the safety and the  
496 risk-benefit ratios of these interventions.

### 497 **Study Limitations**

498         The results of all studies we reviewed should be interpreted with caution. Eight of the  
499 nine randomized studies were classified as “high risk” of bias and one was classified as “some  
500 concerns”; all NRCT and one-group studies were deemed as “serious risk” of bias. One  
501 limitation present in all studies of NBA interventions is the impossibility of keeping the  
502 participants unaware of the intervention they are receiving (i.e., blinding). Participants always  
503 know when they are in the NBA group. This lack of blinding might influence participants’  
504 decision to search for additional care if they are not satisfied with the group they were  
505 assigned to, or it might bias their reporting of depressive symptoms (Rosa & Delabrida, 2021;  
506 Sterne et al., 2019; Sterne, Hernán, et al., 2016). Nonetheless, a recent study assessing the  
507 impact of participants' awareness of the intervention (i.e., lack of blinding) on studies' results  
508 did not find evidence that this design limitation impacted the results (Moustgaard et al.,  
509 2020). Another limitation of all studies except one (i.e., Walter et al., 2019) was the lack of a  
510 registered analysis plan matching the analyses performed in the manuscript, ensuring that  
511 reporting of results was not selective. Some RCTs did not report enough information to prove  
512 that the strategy used to allocate participants to groups was random and concealed (see Sterne  
513 et al., 2019, for details about allocation concealment). Additionally, some studies had a  
514 considerable amount of missing data from baseline to post-intervention, which can bias the  
515 interpretation of an intervention's effect on depressive symptoms under some conditions  
516 (Sterne et al., 2019; Sterne, Hernán, et al., 2016).

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517           Specific to NRCTs is the possibility of systematic baseline difference between groups  
518 in variables that can predict the outcome of interest (i.e., prognostic variables). If groups  
519 differ in prognostic variables, such as baseline mean depression score, then differences in the  
520 outcome of interest might be explained by other factors than the intervention. Studies without  
521 a comparison group are also constrained because it is not possible to estimate what would  
522 have occurred had the intervention group not received the intervention. For instance, observed  
523 changes in studies with only an intervention group might be explained by factors such as  
524 external events that occurred during the intervention period, placebo effect, regression to the  
525 mean, and random or systematic error in the measurement of the outcome (Rosa & Delabrida,  
526 2021; Sterne, Hernán, et al., 2016; Thomas et al., 2020). Thus, when interpreting the results of  
527 studies in this review, it is important to remember that more biased estimates of effect tend to  
528 come from NRCTs and studies without a control group than from randomized studies.

529           Whereas all included studies may have been affected by some kind of bias, it is  
530 unknown how much this bias explains the estimates of NBA intervention effects that we  
531 observed. When considering studies with a similar risk of bias researchers may have more  
532 confidence in studies with larger samples and larger estimates than in studies with fewer  
533 participants and smaller estimates. It is also important to note that while a high risk of bias  
534 occurs due to limitations in study design, it does not always imply biased estimates  
535 (Moustgaard et al., 2020). Future research is needed to understand how study design may  
536 influence the studies' results. Additionally, adherence to relevant Consolidated Standards of  
537 Reporting Trials (CONSORT) would improve the interpretation of the results for NBA  
538 intervention studies (Moher et al., 2010).

539           In addition to these limitations, a systematic review involves many decisions that  
540 influence the interpretation of findings (Higgins et al., 2019). Here we also point out how our  
541 decisions impact the interpretation of findings. First, we did not limit this review to specific

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542 populations (e.g., adults), interventions (e.g., climbing), and comparison groups (e.g., usual  
543 care). Hence, the included studies are different in important characteristics that preclude  
544 meaningful quantitative synthesis of their results (i.e., meta-analysis). We therefore chose to  
545 present a forest plot with effect estimates from the included RCTs (Figure 3), but we  
546 recommend that readers not focus on the combined estimate from these studies. Instead, they  
547 may consider how different kinds of NBA interventions (including the kind of activities  
548 provided, their length, frequency, and duration) may improve the depressive symptoms of  
549 specific groups (e.g., war veterans) as compared to alternative interventions (e.g., usual care).  
550 To improve understanding of how intervention and participants' characteristics may influence  
551 the study's results, more randomized studies that isolate the impacts of specific variables are  
552 needed. For example, a randomized study could provide a similar intervention to two different  
553 groups of people or a slightly different intervention to the same participants.

554         Second, we included studies independent of whether or not their participants had a  
555 diagnosis of depression because every person can experience depressive symptoms (e.g.,  
556 sleep problems) to a certain degree. In fact, none of the randomized studies we identified  
557 reported a diagnosis of depression for their participants, although some studies were  
558 conducted with people with mental health problems like adults at risk of suicide (Sturm et al.,  
559 2012) and war veterans with Post-Traumatic Stress Disorder (Gelkopf et al., 2013). Thus,  
560 there is a lack of evidence from randomized studies concerning the effect of NBA  
561 interventions on people diagnosed with depression, highlighting a fruitful line for future  
562 research.

563         Third, we did not exclude studies that linked NBA activities with other interventions.  
564 For example, only two of the nine randomized studies included in the systematic review did  
565 not report some type of co-intervention (Table 3). As a result, it was difficult to separate the  
566 possible effect of the NBA activities versus the effects associated with co-interventions.

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567 Sturm et al. (2012) was one of the few exceptions because the co-intervention (i.e., usual care)  
568 was offered to both the NBA group and the comparison group. More studies with designs  
569 enabling isolation of the potential effect of NBA activities are needed.

570 Fourth, despite focusing on randomized studies, we included studies with other  
571 designs to generate a more comprehensive overview of how NBA has been used in depression  
572 research. This more inclusive approach allowed us to identify some reasons for dropout and  
573 adverse events that were not reported by randomized studies. Results from non-randomized  
574 studies could help inform the direction of future studies. For example, four non-randomized  
575 studies that involved surfing with adult samples found considerable improvement in their  
576 depressive symptoms (Table 1 in Supplementary File 2); therefore, future randomized studies  
577 using surfing as an intervention for adults may be warranted.

578 Finally, concerning our methodology, only one researcher conducted the title and  
579 abstract screening. This approach was efficient, but the risk of inadvertently excluding a  
580 potentially relevant study might have been reduced if two researchers were involved in this  
581 process. Unfortunately, this was a necessary decision to allow the execution of this systematic  
582 review. Moreover, no systematic review is expected to include all studies relevant to the  
583 research question since no search strategy is 100% effective (Higgins et al., 2019).

### 584 **Conclusions and Next Steps**

585 Our systematic review is, to date, the most comprehensive summary of studies  
586 estimating the effect of NBA interventions on depression. We found average estimates of  
587 effects that vary from large reductions in depressive symptoms to moderate increases in these  
588 symptoms. Overall, we observed a high degree of variability across studies in terms of  
589 participants and NBA activities, even when considering a specific type of NBA activity (i.e.,  
590 surfing). Thus the variability in the effects of NBA interventions on depressive symptoms  
591 may depend on the participants' and NBA activities' characteristics (e.g., length, frequency,



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592 duration). Variability in participants and NBA activities makes it difficult to provide specific  
593 guidelines about the most effective NBA interventions. However, our findings provide some  
594 hints about ways of reducing depressive symptoms through NBA interventions. Considering  
595 studies with the most reliable design (i.e., randomized studies), the largest reductions in  
596 depressive symptoms were observed in studies with adults that combined mountain-based  
597 interventions (see Table 4) with other forms of care, such as psychotherapy (Shin et al., 2012;  
598 Sturm et al., 2012). Additionally, all four included studies with adults that used surfing as the  
599 only NBA activity found a considerable reduction in depressive symptoms from baseline to  
600 post-intervention (Table 1 in Supplementary File 2). Similar to the mountain-based RCTs,  
601 three of the four surfing interventions reported complementary interventions like mindfulness,  
602 yoga, and socialization. This suggests that mountain-based and surfing interventions  
603 associated with other forms of care can reduce substantially adults' depressive symptoms.

604 Overall, existing evidence justifies the continued study of NBA activities as  
605 interventions for reducing depressive symptoms. However, it may also indicate that some  
606 NBA activities are not worth the risk, given the potential for adverse events (Finkenzeller et  
607 al., 2011; Müller et al., 2011). Efforts should be directed to replicate (with more informative  
608 designs) NBA interventions that found substantial improvement in depressive symptoms,  
609 experienced low dropout rates, and were relatively safe. Variability in dropout across studies  
610 suggests some NBA interventions may be more attractive or safer than others, leading to  
611 increased adherence. Given the potential for serious adverse events in NBA interventions that  
612 may lead to dropouts, it is critical to conduct risk-benefit assessments before initiating the  
613 intervention. Future studies should report the number of participants who dropped out from  
614 the groups as well as information related to adverse events (even if no event was observed).  
615 This will favor a more critical evaluation of the adherence and risk associated with NBA  
616 interventions. More randomized studies assessing the impact of the NBA interventions on

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617 depressive symptoms are also needed. This may include studies relating the health effects of  
618 comparable indoor adventure activities (e.g., wall climbing) to those of NBA activities (e.g.,  
619 mountain climbing). Randomized studies conducted in countries of the Global South are also  
620 absent, as well as research conducted with people diagnosed with depression. In general,  
621 study designs should allow researchers to realize the unique or added benefits of NBA  
622 activities.

623         Future systematic reviews could also explore other outcomes relevant to understanding  
624 the potential value of NBA interventions, including the possible effects of these activities on  
625 other mental (e.g., anxiety, loneliness, and anger) and physical outcomes (e.g., weight loss).  
626 Systematic reviews that directly assess the effect of NBA on specific symptoms of depression  
627 (e.g., mood and anhedonia) are also warranted since our review focused on aggregate scores  
628 from depression outcome measures, not on specific symptoms. Finally, studies should  
629 consider the financial cost of implementing NBA interventions relative to other more  
630 conventional strategies commonly employed to prevent or treat depression and other mental  
631 health disorders, highlighting the relative value of NBA interventions compared to other  
632 alternatives.

### 633   **Declaration of Interest Statement**

634         The authors declare they have no conflict of interest.

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875

## NATURE-BASED ADVENTURE INTERVENTIONS

**Table 1**

*Eligibility criteria for our systematic review of the effects of nature-based adventure (NBA) interventions on depression based on population (P), intervention (I), comparison groups of interest (C), outcomes (O), and study designs (S)*

PICOS	Description
Population	Studies with humans at any age, healthy or unhealthy
Intervention	Studies that provide or consider any form of NBA intervention. We define NBA intervention as the promotion of one or more activities of adventure in a natural setting
Comparison groups of interest	Studies with any comparison/control group and studies without a control group
Outcomes	Studies that assess depression using a measure designed to measure depression. At least one study (i.e., a validation study) should exist describing how the content of the measure matches the construct's content (i.e., depression)
Study design	Randomized and non-randomized studies of interventions

## NATURE-BASED ADVENTURE INTERVENTIONS

Table 2

*Main characteristics of the randomized studies included in this systematic review of studies investigating effects of nature-based adventure (NBA) interventions on depression*

First author (year)	Participants	Mean age or age range	Women %	Time (T) in which data was collected <sup>a</sup>	Depression measure	Country	Setting where the nature-based adventure intervention took place
Parallel-group randomized controlled trials							
Loy (1999)	Bereaved adolescents	13.6	55.7	<b>Experimental group:</b> T1: Week following the camp program <b>Comparison group:</b> T1: Week before the camp began	Reynolds Adolescent Depression Scale	United States	A 45-acre lake surrounded by a 400-acre wildlife refuge
Li (2013)	Primary schoolchildren	11.61	47.5	T1: At recruitment T2: After the intervention	Center for Epidemiologic Studies Depression Scale for Children	China	Camp
Chung (2021)	Secondary school students	13.0	45.2	T1: At baseline T2: 3 months after the intervention	The Chinese version of the Center for Epidemiologic Studies Depression Scale for Children	China	Temporary campground with adventure-based training facilities
Putra (2016)	Junior High School students	NI	NI	T1: Before the intervention T2: After the intervention	Depression Anxiety Stress Scales	Indonesia	Camps
Pereira (2020)	Children and adolescents in residential childcare	13.83	41.6	T1: Before the intervention T2: After the intervention	The Revised Children's Anxiety and Depression Scale	Portugal	Carcavelos beach
Finkenzeller (2011)	Individuals who are 60+ years of age	60 to 76	48.9	T1: Before the intervention T2: After the intervention	General depression scale-short	Austria	Salzburg Ski Amade (altitude 728–2700 m)
Shin (2012)	Alcoholics	45.26	8.7	T1: Just before the intervention T2: After the intervention	Beck Depression Inventory	South Korea	Saneum Recreational Forest
Gelkopft (2013)	War veterans diagnosed with Post-traumatic stress disorder	24 to 59	0	T1: Before randomization T2: After 12 months	7-item brief Beck Depression Inventory Fast Screen	Israel	Sea
Randomized crossover trial							
Sturm (2012)	Adults at risk of suicide	43.05	70	<b>First adventure:</b> T1: Before hiking; T2: After hiking; T3: After control <b>First control:</b> T1: Before control; T2: After control; T3: After hiking	Beck Depression Inventory	Germany	Mountain

*Note.* <sup>a</sup> Only information related to data used in our analysis. NI = No information.

## NATURE-BASED ADVENTURE INTERVENTIONS

**Table 3**

*Description of nature-based adventure (NBA) activities, comparison group activities, and co-interventions of the randomized studies included in the systematic review*

First author (year)	Nature-based activities and comparison group activities	Co-interventions	Intervention length <sup>a</sup>	Intervention frequency <sup>b</sup>	Session duration <sup>c</sup>	Group N
Loy (1999)	<b>NBA group:</b> Camp, which included hiking, canoeing, and paddle boat, among other activities available for children.	Other leisure activities and group work to help children deal with their grief.	Two days	Daily	No information	25
	<b>Comparison group:</b> No intervention.	NA	NA	NA	NA	36
Li (2013)	<b>NBA group:</b> Camp activities including low rope course, rock climbing, canoeing, and orienteering.	Five education sessions (around 75 minutes each) plus indoor activities during the 1-day camp	10 months	One day of NBA activities	Three and a half hour	56
	<b>Comparison group:</b> Five sessions of leisure activities, which included a cartoon film show, handicraft workshops, a health talk on the prevention of influenza, and age-appropriate physical leisure activities, such as table tennis, badminton, chess, and Chinese billiards. Additionally, children were invited to join a day visit to Hong Kong Ocean Park at the end of the academic year.	NA	10 months	No information	75 minutes of leisure activities	64
Chung (2021)	<b>NBA group:</b> Crossing a river with planks and 5km nocturnal trail hiking.	Thinking and talking about the experiences, ways to overcome difficulties, and situations in life similar to the ones faced during the intervention. Health educational talks. Many indoor activities (e.g., wall climbing).	Two days and one night	Daily	One hour and 15 minutes crossing the river and two hours of nocturnal hike	115
	<b>Comparison group:</b> Leisure activities, including film shows, handicraft workshops, table tennis, badminton, chess games, Chinese billiards, and a half-day visit to a museum. These recreation activities mimicked the amount of time and attention required by the experimental group. Health educational talks.	NA	Two days	Daily	From 45 minutes to three hours and 15 minutes	113
Putra (2016)	<b>NBA group:</b> Camping and hiking. Activities included setting up a tent, cooking, bonfire, traveling tea plantations, and climbing hills.	No information	3 days and 2 nights	Daily	From one hour to three hours	20
	<b>Comparison group:</b> No intervention.	NA	NA	NA	NA	20

## NATURE-BASED ADVENTURE INTERVENTIONS

First author (year)	Nature-based activities or control-group activities	Co-interventions	Intervention length	Intervention frequency	Session duration	Group N
Pereira (2020)	<b>NBA group:</b> Twenty-one sessions of surfing suited to each participant given their level of surfing practice.	Group discussion about last week's experiences and feelings and group activities or reflection related to the theme of the week and to develop the socio-emotional skills defined for the session (e.g., non-violent communication, empathy, self-confidence).	From January to June	Once a week	Three hours	33
	<b>Comparison group:</b> Waiting list group.	NA	NA	NA	NA	32
Finkenzeller (2011)	<b>NBA group:</b> Guided alpine skiing in groups of four to seven participants.	No information	12 weeks	Three times a week	Up to four hours	18
	<b>Comparison group:</b> Participants were asked to live their normal life but were not allowed to ski during the study.	NA	NA	NA	NA	15
Shin (2012)	<b>NBA group:</b> Mountain-climbing, tracking, and orienteering.	Other activities in forest, meditation, and counseling.	Nine days	Daily	No information	47
	<b>Comparison group:</b> No intervention.	NA	NA	NA	NA	45
Gelkofft (2013)	<b>NBA group:</b> 40 sailing instructions and practice held in groups of six to 10 people plus two 3-days outdoor activities including outdoor sleeping, camping, and rowing.	Group talks about participants' experiences and social activities during the two 3-days outdoor activities.	One year	Once a week sailing instructions and practice	Three hours of sailing instructions and practice	22
	<b>Comparison group:</b> Waiting list.	NA	NA	NA	NA	20
<b>Randomized crossover trial</b>						
Sturm (2012)	<b>NBA activity:</b> Mountain hiking <b>Comparison activity:</b> No intervention.	Usual care NA	Nine weeks Nine weeks	Three times a week NA	Two to three hours NA	17

*Note.* Different activities included in an intervention may have had different lengths, frequencies, and duration.

<sup>a</sup> Intervention length refers to the duration of the full intervention. <sup>b</sup> Intervention frequency refers to the frequency of the NBA activities or comparison group activities. <sup>c</sup> Session duration refers to the duration of the NBA activities or comparison group activities provided during each session. NA = Not applicable.



## NATURE-BASED ADVENTURE INTERVENTIONS

**Table 4**

*Percentage of change from baseline in depression scores, standardized mean change, number of participants who had a  $\geq 50\%$  reduction on depression scores from baseline to post-intervention (i.e., responders), dropouts, and adverse events in the nature-based adventure (NBA) and comparison groups of randomized studies included in this systematic review*

First author (year)	Group	% change from baseline <sup>a</sup>	Standardized mean change <sup>b</sup>	Responders <sup>c</sup>	Dropouts	Adverse events
Parallel-group randomized controlled trials						
Loy (1999)	NBA	NI	NI	NI	0/26	NI
	Comparison	NI	NI	NI	1/36	NI
Li (2013)	NBA	-25.44	-0.51	NI	0/56	NI
	Comparison	2.56	0.05	NI	0/64	NI
Chung (2021)	NBA	-10.78	-0.58	NI	0/115	None
	Comparison	0.00	0.00	NI	0/113	None
Putra (2016)	NBA	-6.28	-0.22	NI	NI	NI
	Comparison	8.00	0.17	NI	NI	NI
Pereira (2020)	NBA	7.06	0.10	NI	12/45	NI
	Comparison	-10.75	-0.19	NI	12/44	NI
Finkenzeller (2011)	NBA	NI	NI	NI	9/27	Serious adverse events: 5/27 Falls: 17/21
	Comparison	NI	NI	NI	5/20	NI
Shin (2012)	NBA	-64.04	NI	29/47	NI	NI
	Comparison	0.20	NI	10/45	NI	NI
Gelkopft (2013)	NBA	-10.12	-0.58	NI	6/28	NI
	Comparison	3.71	0.13	NI	0/20	NI
Randomized crossover trial						
Sturm (2012)	NBA	-48.15	-1.18	8/17	3/20	NI
	Comparison	21.05	0.29	2/17	NI	

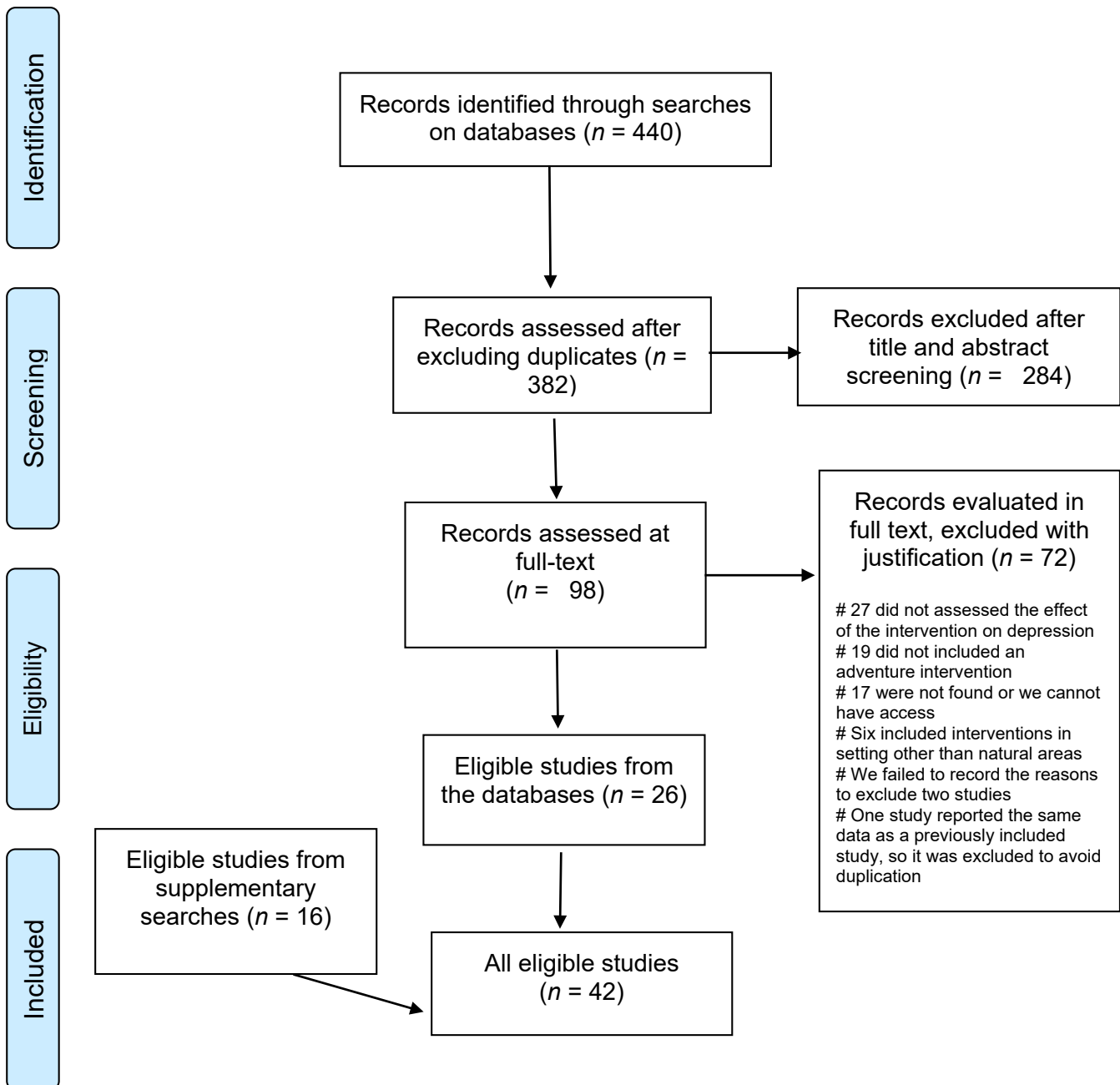
*Note.* Negative values for change from baseline and standardized mean change signify reductions of depressive symptoms.

<sup>a</sup> Change in score divided by baseline score times 100. <sup>b</sup> Change in score divided by the baseline standard deviation. <sup>c</sup> Estimated using the formulae described by Furukawa et al. (2005). NI = No information.

## NATURE-BASED ADVENTURE INTERVENTIONS

**Figure 1**

*Flowchart illustrating the process of searching and selecting studies in our systematic review investigating effects of nature-based adventure (NBA) interventions on depression*



## NATURE-BASED ADVENTURE INTERVENTIONS

**Figure 2**

*Risk of bias of the parallel-group randomized controlled trials included in our systematic review investigating effects of nature-based adventure (NBA) interventions on depression*

		Risk of bias domains					
		D1	D2	D3	D4	D5	Overall
Study	Chung 2021						
	Finkezeller 2011						
	Gelkopft 2013						
	Li 2013						
	Loy 1999						
	Pereira 2020						
	Putra 2016						
	Shin 2012						

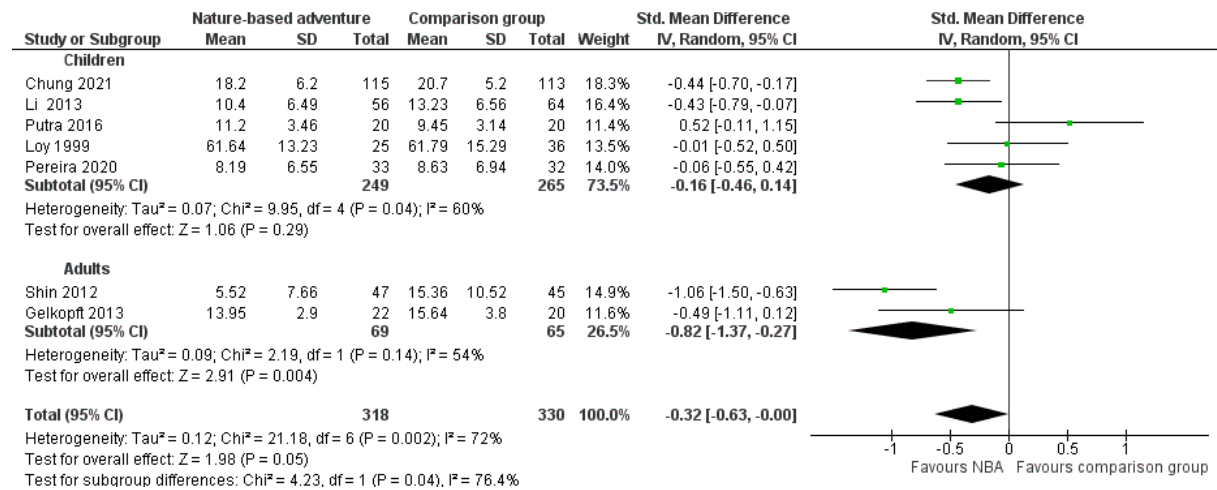
Domains:  
D1: Bias arising from the randomization process.  
D2: Bias due to deviations from intended intervention.  
D3: Bias due to missing outcome data.  
D4: Bias in measurement of the outcome.  
D5: Bias in selection of the reported result.

Judgement  
 High  
 Some concerns  
 Low

## NATURE-BASED ADVENTURE INTERVENTIONS

**Figure 3**

*Standardized differences in post-intervention depression scores from seven parallel-group randomized controlled trials assessing the effect of nature-based adventure (NBA) interventions on depressive symptoms*



*Notes.* The first five studies (from above to below) were conducted with children and the last two with adults. Green squares refer to standardized mean differences, with bigger squares indicating a greater sample size. The diamond represents the combined estimate from the RCTs through a random-effects meta-analysis, but we caution against the interpretation of this estimate because there are considerable differences in individual studies' characteristics.