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1 Abstract

2 Many physical activity (PA) interventions implemented to tackle the child obesity
3 epidemic have shown limited effectiveness, possibly due to a lack of consideration of
4 potential stress that accompanies behavior adaptation and the automatic perseverative
5 cognition that exacerbates the stress (namely rumination). **Purpose:** The main aim of
6 this paper is to develop and validate the PA-specific Rumination Scale for Children
7 (PARSC) that assesses children's tendencies to engage in repeated negative thoughts
8 about PA (Study 2). Items in the scale were derived from qualitative information about
9 factors that inherently demotivates PA participation (intrinsic barriers) through the
10 lived experience of UK children (Study 1). **Methods:** For Study 1, pedometry PA data
11 were collected from 143 children (aged 6-10 years). Twenty-one focus groups were
12 formed based on participants' year group, sex and PA level. For PARSC validation
13 (Study 2), 382 children completed the questionnaire twice. Self-reported PA, objective
14 PA and avoidant coping were also assessed. **Results:** Study 1 – Four overarching
15 themes identified as intrinsic barriers were lack of competence, fear of negative
16 experiences, external constraints and lacking a sense of purpose. Altogether, ten higher
17 order and lower order themes were used to construct PARSC items. Study 2 - From
18 Rasch analysis, PARSC possessed sound internal validity, internal consistency and
19 test-retest reliability. Self-reported PA and avoidant coping were predictive of PA-
20 specific rumination, but not objective PA. **Conclusion:** PARSC is a useful tool to
21 identify children ruminative about PA for whom interventions can be designed, with
22 the intrinsic barriers considered, to promote PA behavior adaptation.

23 Introduction

24 In the past 4 decades, child obesity has become a global issue with an upward
25 surge by more than tenfold, from 11 million in 1975 to 124 million in 2016 (NCD-
26 RisC, 2017). In the UK, about a third of children aged 2-15 are overweight or obese,
27 and the accompanying consequence is the development of cardiovascular diseases
28 which are likely to be carried to adulthood if left untreated (Conolly & Davies, 2017;
29 Llewellyn et al., 2016). Recognising habitual physical activity (PA) to be one of the
30 most modifiable lifestyle factors to curb the epidemic, the number of PA interventions
31 has increased exponentially over the years, however, these initiatives have presented
32 limited (long-term) effectiveness in increasing habitual PA or improving metabolic
33 health status in children (Ells et al., 2018; Wang et al., 2015). A possible reason for
34 the lack of fruitfulness is that interventions commonly target reflective (explicit)
35 processes that assume individuals' awareness (e.g., intention, self-efficacy) instead of
36 automatic (implicit) processes that may directly drive health behaviors (e.g.,
37 impulsivity, attention bias) (Sheeran et al., 2016). Often these implicit processes are
38 unconscious responses that hinder successful behavior adaptation but have been
39 neglected in health behavior research (Larsen & Hollands, 2021).

40 For inactive children, having to move more could be stressful as it deprives
41 them the 'pleasure' of being inactive or engaging in sedentary activities, or, because
42 it is simply unenjoyable. An implicit process that perpetuates stress response and can
43 impede behavior adaptation is rumination. Rumination refers to the tendency to
44 passively and repeatedly engage in negative thoughts about past, present or future
45 events (Nolen-Hoeksema et al., 2008). This cognitive-affective response can be
46 elicited across situations (trait) or in certain situations/context (state) (Smith & Alloy,
47 2009). Rumination is proposed to originate from the lack of goal attainment - a sense

48 of unfulfillment, that ‘something is missing’ (Martin & Tesser, 1996). Individuals with
49 this brooding cognition tend to magnify negative affects while avoid (thoughts of) the
50 stressors as they can cause heightened psychological and/or physiological stress
51 reactivity (LeMoult et al., 2013; Ottaviani et al., 2016; Kocsel et al., 2019).
52 Ruminators’ tendency to suppress negative thoughts ironically increases their
53 accessibility and makes them recurrent (Wegner, 1994). Neurophysiological evidence
54 indicates that people who are more reactive to stress, thus less capable of coping with
55 stress, are more likely to get stuck in this rigid cognition even when the stressors are
56 long gone, brooding rumination is thus considered a maladaptive coping response
57 (Thayer et al., 2009; Brosschot, 2017). Experimentally, ruminators also demonstrated
58 poorer ability to inhibit information that is no longer relevant when they were in a
59 negative mood, yet they were more able to ignore distractors that prevent them from
60 reaching task goals than non-ruminators (Whitmar & Gotlib, 2013). Unsurprisingly,
61 rumination is consistently linked to various psychological disorders such as depression
62 and anxiety (Iqbal & Dar, 2015). Applying rumination to PA behavior, children with
63 high trait rumination tendencies were notably more inactive than their low rumination
64 counterparts, and their habitual PA level was also significantly lower than the
65 recommended PA level (Ling et al., 2010). In adults, high ruminators were also less
66 physically active than low ruminators, mediated by amotivation (Riley, Park &
67 Laurenceau, 2019). Among the high ruminators, the involuntary recurrent negative
68 thoughts about PA may have stopped them from being active. Interestingly, resonating
69 with the goal attainment proposition about rumination, in Ling et al.’s (2010) study,
70 high ruminators were significantly more active than the low ruminators at the initial
71 PA measurement period, but their PA level dropped substantially after 3 weeks and
72 stayed at the same level subsequently, reflecting their baseline habitual PA. The

73 authors speculated that high ruminators may have been motivated to be more active as
74 they were aware of the PA measurement, hence they attempted to fulfil the ‘goal’
75 knowing that they were physically inactive. However, as the stress from being active
76 increasingly sapped their cognitive loads, they could not keep up with (the thought of)
77 being active, hence the return to the PA baseline shortly after the start of the PA
78 measurement. Thus, while ruminators have been found to cognitively avoid the
79 (thought of the) stressors, paradoxically, they seem to also approach the stressors for
80 a while, resonating with the goal attainment conceptualisation of rumination as
81 previously discussed (Martin & Tesser, 1996; Dickson et al., 2012).

82 Taken together, it appears that the relationship between rumination and
83 negative PA behavior exists, possibly due to ruminators’ tendencies to dwell on PA-
84 related negative thoughts and/or experiences (Ling et al., 2015). However, research
85 into the relationship between rumination and PA behavior is scarce, particularly in
86 children, even though rumination has been linked to other negative health behaviors
87 (Riley, 2019). A common limitation for the above-mentioned studies on rumination
88 and PA behavior is that the instruments used to measure rumination tendencies were
89 for evaluating trait rumination, and not specific to PA behavior. While trait rumination
90 has advanced our understanding of why people engage in maladaptive health
91 behaviors - as a means of coping with daily stress (Riley, Park & Laurenceau, 2019),
92 context-specific state rumination can shed light on why people fail to adapt positive
93 health behaviors. Additionally, it is evidenced that with practice, state rumination can
94 develop into trait rumination as children’s metacognition develops (Shaw et al., 2019).
95 It is thus imperative that rumination tendencies are identified and intervened at an
96 early age. To date, there are no validated instruments to measure rumination
97 tendencies towards PA participation. Therefore, main aim of this investigation (Study

98 2) is to develop and validate the PA-specific Rumination Scale for Children (PARSC).
99 Items for the new instrument will be generated from a focus group study (Study 1) on
100 factors that intrinsically demotivate PA participation (intrinsic barriers), i.e., reasons
101 for the inherent dislike for PA, such as discomfort from being out of breath) in UK
102 children. We will test the internal validity, internal consistency, predictive validity and
103 test-retest reliability of PARSC. We expected that avoidant coping and objective PA
104 would be predictive of PA-specific rumination.

105

106 **Study 1**

107 **Method**

108 The aim of Study 1 is to explore the intrinsic barriers of PA through the lived
109 experiences of school-aged children in focus group discussions. This study adopts the
110 relativistic ontology which stipulates that subjective reality exists in every individual
111 (Denzin & Lincoln, 2005). To ensure rigor, we considered the following – i) how to
112 build rapport with the participants and conduct the discussions so that the data co-
113 created provides insights into their physical and emotional experiences; ii) how to
114 relate different experiences from diverse backgrounds; iii) how to critically reflect on
115 the interviewers'/researchers' preconception about children's experience in both the
116 data collection and data analysis stage (Sparkes & Smith, 2009). These considerations
117 have been addressed in the sections below. The themes generated will inform the
118 development and validation of the PA-specific Rumination Scale for Children
119 (PARSC) in Study 2.

120

121 **Participants**

122 Table 1 summarises the sample characteristics. One hundred and forty-three
123 children aged 6 to 10 years (Year 2 to 5; $M_{age} = 8.77$ yrs, $SD = 1.05$; 50% boys) assented
124 to participation and parental consents were received. Participants were recruited from
125 4 government-aided primary schools in the southwest of UK through the first author's
126 introduction of the project to the pupils during school assemblies who then passed on
127 the study information sheet to their parents/guardians to consider. Following Levitt et
128 al.'s (2017) guidelines on upholding fidelity and utility of qualitative research, the
129 recruited schools were from areas of different social economic status so that the data
130 can capture diversity of experiences, in addition to the included age range and PA level,
131 hence the results are contextualised (see Procedure below). Also, age-appropriate
132 language was used throughout the study. All measures and procedure were approved
133 by the Institutional Ethics Board.

134

135 --- *insert Table 1 here* ---

136 **Procedure**

137 Focus group discussions were conducted in this study as children's familiarity
138 with each other could build rapport more easily given the limited discussion time, and
139 that their views could encourage self-reflections amongst themselves (Levitt et al.,
140 2017; Adler et al., 2019). To aid the random selection of participants for focus group
141 discussions based on their habitual PA, all participants were given a peizo-electric
142 pedometer (New Lifestyles 800) to wear over a nylon belt on their left hips every day
143 during waking hours, except during water activities, for 3 consecutive weeks. The New
144 Lifestyles 800 has presented good validity as a measurement tool for school-aged
145 children (Ling et al., 2011). To account for potential reactivity, all pedometers were
146 sealed and only Week 3's data were used to categorize participants into low, moderate

147 and high PA for each year group (Ling et al., 2011). Participants with at least 1
148 weekday and 1 weekend day of data in Week 3, with daily steps between 2,000 –
149 30,000 inclusive, were included in the analysis for Study 1 and Study 2 (Rowe et al.,
150 2004).

151 Focus groups were composed based on sex, year group and high/low activity
152 level, hence each year group consisted of at least one group of high PA boys, one
153 group of high PA girls, one group of low PA boys and one group of low PA girls
154 (Adler et al., 2019). Most focus group discussions lasted for 20-30 minutes and were
155 led by the first author who has extensive experience working with this population.
156 Some year groups had more than 2 focus groups due to insufficient time to complete
157 the earlier sessions. Most focus groups consisted of 3 participants each, but due to
158 absence on the date of discussions, one group only had 2 participants. Altogether 53
159 participants were included in 19 focus group discussions across all year groups. The
160 two researchers responsible for data analysis considered further focus group
161 discussions were unlikely to yield additional themes or insights into the research
162 question, thus no further interviews were arranged (Levitt et al., 2017; Adler et al.,
163 2019). All focus group discussions were conducted within the respective school
164 venues (see Table 2 for details).

165

166 --- *insert Table 2 here* ---

167

168 Semi-structured interview questions were prepared to prompt the discussions
169 and these questions primarily tapped into participants' daily routine and the reasons
170 for disliking PA (Peterson-Sweeney, 2005). Open-ended questions and prompts were
171 constantly used to ensure optimal understanding of participants' lived experiences and

172 to steer away from the researchers' existing knowledge. Another means to enhance
173 fidelity to the subject matter is through constant reminders amongst the researchers
174 that participants' experiences should not be assumed during the focus group
175 discussions nor in data analysis (Levitt et al., 2017). At the start of every focus group
176 discussion, the concept of PA was clarified to ensure that the participants understood
177 that all sports, exercise, play or everyday activities (e.g., walking to school) would be
178 considered as PA. To aid the discussions, participants were first asked to draw the
179 activities they did not enjoy, so as to allow time to reflect on their experiences and
180 further engage in the subsequent discussions (Morgan et al., 2002). In particular,
181 participants were asked to reflect on the thoughts that were conjured up as they were
182 drawing the activities that they disliked, or if they were to participate in them, as this
183 information would serve the aim of Study 2. All focus group discussions were audio-
184 recorded and transcribed verbatim.

185

186 **Focus group analysis**

187 Two researchers conducted thematic analysis using QSR NVIVO 12 software.
188 Specifically, thematic analysis akin to Braun and Clarke's (2019, 2021) coding
189 reliability approach was adopted as themes were generated through participants'
190 explicit mentioning of the intrinsic barriers to PA, rather than through the more open
191 interpretative approach to data analysis. The coding reliability approach was
192 considered more appropriate given the study aim and the limited time allocated to each
193 focus group. The researchers first familiarised themselves with the transcripts, then a
194 deductive approach was initially employed, followed by an inductive approach, as
195 recommended for analyses that are partially addressing existing theories (Elo &
196 Kyngäs, 2008). The researchers first coded and organised the data into higher order

197 and lower order themes independently in order to ensure fidelity to the research topic
198 (Levitt et al., 2017). Following the relativist approach, the researchers acted as critical
199 friends in order to encourage reflections and challenge the interpretations of how the
200 data was understood so as for a coherent story of the participants' lived experiences to
201 emerge (Levitt et al., 2017, Smith & McGannon, 2018). Data analysis concluded when
202 both researchers had reached saturation in the analysis and that the final coding scheme
203 could sufficiently addressed the study aim.

204

205 **Results**

206 Four themes emerged as central to why children were disengaged from PA.
207 These are concerned with a lack of competence, fear of negative experiences, external
208 constraints and a lack of purpose (Table 3).

209 --- *insert Table 3 here* ---

210 Lack of competence

211 When children failed to experience a sense of accomplishments in certain
212 activities, they tended to stop engaging. Many attributed the lack of competence to
213 their ability, and some had linked it to their natural built (e.g., in playing basketball).
214 Varying degrees of resilience towards the lack of competence were demonstrated,
215 whereby some would persist but some would stop trying after a few attempts.

216 I can't learn (to play football) because I never go to sports club, [...] 3 times I don't
217 catch it then I quit. [Low active boy, Year 3]

218 Confidence might be further dampened when children attributed social
219 exclusion in PA participation to their lack of competence, and this might lead to
220 further avoidance of participation.

221 I never get to jump over the rope, and everyone called me that I need to hold [the
222 rope] and wrap it round for people to go on it. [High active girl, Year 2]

223 Nobody let me be a goalie, but sometimes well I'm terrified at goalie. [High active
224 boy, Year 2]

225

226 Fear of negative experiences

227 Resonating the avoidance tendency was the prominent theme of fear across all
228 focus groups. Children could be fearful of getting hurt and experiencing accidents
229 during PA.

230 [I don't want to do gymnastics] because you can hurt yourself because I saw it this
231 one year in the Olympics. This guy banged his leg on this thing and it just like broke.
232 And [I don't like] tennis because if you whack too hard you can sprain your wrist or
233 something. [High active girl, Year 5]

234 I don't like [swimming] because I always think when you swim you might drown.
235 [Low active boy, Year 3]

236 The above examples suggest that some children were not only fearful about
237 experiencing negative incidents again, but also accidents that had not happened to
238 them before. Another bodily experience that some children tried to avoid was bodily
239 discomfort such as "stitches" and "headaches". Interestingly, some children
240 considered being "out of breath" as negative which was associated with being
241 "tired", hence aerobic activities such as running and swimming were undesirable.
242 Lastly, younger children and older girls tended to be weary about "getting dirty"
243 during PA which also had influence over their choice of activities. Worth noting also
244 is that only one girl mentioned about being "sweaty" was a reason for not engaging
245 in PA.

246

247 External constraints

248 Some external factors were less frequently mentioned but nonetheless
249 appeared to play a role in children's PA participation. One of them was time
250 constraints due to schoolwork commitments. A minority of children had expressed
251 that they would have liked to engage in more PA if they did not have schoolwork.
252 Furthermore, primarily younger children, disliked activities that either were sex-
253 stereotyped or involved the other sex who behaved differently.

254 [I don't like football] because boys don't really like girls and girls don't really like
255 boys and there will be a mess and will shout at each other, and I don't like that.

256 [Low active girl, Year 2]

257 [I don't dance because] it makes you feel like a girl. [Low active boy, Year 3]

258

259 Even though mainly girls expressed their disapproval of boys' behavior during
260 activities, it was also a case of unfair play that deterred engagement, such as previous
261 experiences of "rough" play or intentional "pushing".

262

263 Lack of purpose

264 The final theme that appeared to be an intrinsic barrier to PA engagement for
265 some children is a sense of 'what's the point?'. It was neither liking nor disliking, but
266 perhaps this sentiment came from a dissociation between the activities and the
267 identified facilitators.

268 Because you just kick a ball and that's it, what's the whole point about football?

269 [High active boy, Year 3]

270 I always think that you're just running around to kick the ball and score a goal (and
271 that's it!) [Low active girl, Year 5]

272

273 To sum up, four higher order themes have been identified as intrinsic barriers
274 of PA and lower order themes have been classified under two of them (see Table 3
275 for details). In total, ten themes (higher order and lower order) have been used to
276 construct the PA-specific Rumination Scale for Children (PARSC) in Study 2.

277

278 **Study 2**

279 Study 2 aims to develop the PA-specific Rumination Scale for Children
280 (PARSC) using a modern psychometric approach to determine the internal validity
281 and internal consistency of the scale. Additionally, test-retest reliability and factors
282 predictive of PA-specific rumination tendencies, namely avoidance coping, objective
283 and subject PA, will be assessed.

284 PARSC will be assessed using an analytic approach based on Rasch
285 Measurement Theory. This approach provides a basis for investigating a number of
286 psychometric properties of multi-item instruments, and its use has been gaining
287 momentum due to its additional advantages over Classical Test Theory-based
288 approaches. The Rasch model is a probabilistic model that places persons and items at
289 locations along the same underlying latent continuum (of rumination, in this case)
290 (Rasch, 1960). The likelihood of a person's response to an item is simply a product of
291 the difference in location between the person and the item. The Rasch analytic
292 approach allows multiple properties of a psychometric scale to be assessed within the
293 same framework. All individual items are assessed in terms of whether they contribute
294 to the underlying trait, whether response categories are appropriate and working as

295 intended, whether they are statistically dependent with other items in the scale, and
296 whether there is any apparent bias between specific response groups. Additionally,
297 when Rasch modelling assumptions are satisfied, the ordinal scale scores can be
298 transformed to a continuous scale for conceptually sound utilisation in research
299 (Wilson, 2005).

300

301 **Method**

302 **Participants**

303 Three hundred and eighty-nine children aged 6 to 11 years (Grades 1 to 6) were
304 recruited from 5 local primary schools in the UK – 4 from the southwest region
305 (Sample 1 from Study 1; n=143) and 1 from the northeast region (Sample 2; n=246)
306 (45.5% boys; mean age = 8.63 years ± 1.32). Seven participants failed to complete
307 PARSC at both the test and retest time points, hence only 382 cases were included in
308 the analyses (see Table 1). All participants provided written assent and their parents
309 provided written consent. All measures and procedure were approved by the
310 Institutional Ethics Board.

311

312 **Procedure**

313 On a normal school day at their respective schools, all participants completed
314 the PARSC and the PA subscale from the Physical Self-Description Questionnaire –
315 Short version (PSDQ-S; Marsh et al., 2010). Participants completed PARSC twice
316 with 1-2 weeks apart for test-retest reliability. Sample 1 also completed the avoidant
317 coping subscales from the Children's Coping Strategies Checklist (CCSC; Ayers et
318 al., 1996) and wore a peizo-electric pedometer (New Lifestyles 800) (see details from

319 Study 1). For the questionnaires, a researcher read out every question and encouraged
320 participants to ask for clarifications where necessary.

321

322 **Measures**

323 Physical Activity-specific Rumination Scale for Children (PARSC). Out of all the
324 themes identified as the intrinsic barriers of PA from Study 1, 10 have been concurred
325 by the researchers as potential thoughts that may hinder PA participation in young
326 children (Table 3). Each theme was then formulated into a question that reflect the
327 tendencies to engage in that negative thought, e.g., ‘How often do you think you’re
328 bad at it?’ and ‘How often do you think you might get hurt?’. All questions are
329 anchored by an introduction specifying that each question conveys an unpleasant
330 thought that one might have before engaging, while engaging or after engaging in PA
331 (abiding by the definition of rumination). The meaning and examples of PA were also
332 provided. The response scale for each item includes 1 (never), 2 (sometimes), 3 (often),
333 to 4 (all of the time). The number of response choice is deemed appropriate for this
334 age group who may find more choices to be conceptually challenging to distinguish.
335 Additionally, excluding the midpoint could eliminate the ambiguity of the midpoint
336 choice, as it could be interpreted either as neutral or ‘I don’t know’ regardless of the
337 choice description (Streiner & Norman, 2008; Weng, 2004). Wordings of all items and
338 response choices were reviewed by two experienced primary school educators to
339 check for understanding for the target population. Some modifications have been made,
340 e.g., ‘How often do you think that people may play unfairly?’ (item 10) was changed
341 from ‘How often do you think people will not play by the rule?’ as the word ‘fair’ is
342 more commonly used by children than ‘play by the rule’.

343 As a pilot test to further ascertain the face and content validity, two children
344 from each year group were invited to complete PARSC in the presence of a researcher.
345 They were asked to complete the questionnaire by themselves and were encouraged
346 to ask for clarifications. On completion, the researcher asked each child to explain
347 their answers to a few items to ascertain their understanding. Three children expressed
348 that they were occasionally undecided about the response choices, nonetheless, as
349 Rasch analysis will inform the appropriateness of the response scale, no modifications
350 had been made at this stage. As all 10 children appeared to sufficiently comprehend
351 the questionnaire, their data were included in the final analyses. It is worth mentioning
352 that where possible, it would be preferable to read out each item especially to those
353 younger than 8 years of age. This could further aid understanding and completion of
354 the scale.

355

356 Physical Self-Descriptive Questionnaire – short version (PSDQ-S; Marsh et al., 2010).
357 PSDQ-S measures various aspects self-perceived physical attributes such as sporting
358 skills and health. For the purpose of the current study, only the Physical Activity
359 Subscale (four items, e.g., ‘I do lots of sports, dance, gym, or other physical activities’),
360 which measures self-perceived level of PA, was used. The response scale ranges from
361 1 (True) to 6 (False), with no descriptors for the in-between options. The PSDQ-S has
362 consistently demonstrated sound psychometrics to be used in school-aged children
363 (Rudd et al., 2017).

364

365 Children Coping Strategies Checklist (CCSC; Ayers et al., 1996). The CCSC was
366 designed to measure coping strategies adopted by children and adolescents. It is a 52-
367 item self-report inventory, but for validation purpose, only three subscales - repression,

368 wishful thinking and avoidant actions – collectively indicative of the avoidant coping
369 construct were used. Example items are ‘You tried to ignore it’, ‘You wished that
370 things were better’, and ‘You avoided the people or activities that made you feel bad’
371 respectively. Each subscale consists of four items rated on a 4-point Likert scale - 1
372 (never), 2 (sometimes), 3 (often), and 4 (most of the time). The CCSC has
373 demonstrated good internal validity and consistency among school-aged children
374 (Ayers & Sandler, n.d.; Simpson et al., 2018).

375

376 **Analysis strategy**

377 The internal construct validity and psychometric properties of the PARSC were
378 assessed using Rasch analysis with the RUMM 2030 software, utilising a partial-credit
379 model (Andrich et al., 2009). The analysis process was conducted systematically to
380 determine the extent to which the PARSC item set satisfies Rasch model assumptions,
381 and to identify whether any misfit is present. Satisfactory *overall fit* would be
382 indicated by a non-significant Chi-square probability (at $p = 0.05$). *Individual item fit*
383 and *individual person fit* would be determined by fit residual values between ± 2.5 , and
384 a non-significant Bonferroni-adjusted Chi-square probability (at $p = 0.05$) (Ramp et
385 al., 2009; Shea et al., 2009). Additionally, we assessed if the items measure the same
386 underlying construct (*unidimensionality*) as indicated by a series of t-tests determining
387 whether separate subsets of items deliver different person estimates in $<5\%$ of cases
388 (with 95% confidence intervals applied) (Tennant & Conaghan, 2007). To ascertain
389 whether the response to any item had a direct impact on the response to any other item
390 (*local independence*), we inspected if any between-item residual correlation matrix
391 (Q3) values > 0.2 of the matrix average (Marais & Andrich, 2008; Christensen et al.,
392 2017). Response category functioning was assessed through inspection of the

393 threshold map and the category characteristic curves, and the relative person and item
394 location distributions (targeting) were assessed with the person-item threshold map
395 (Pallant et al., 2006). Further, a *differential item functioning (DIF)* test was undertaken
396 to confirm whether responses to any items displayed bias between groups - sex and
397 age groups in our case. This is assessed with the analysis of variance DIF test available
398 in RUMM, where DIF is indicated at $p = 0.05$ (Bonferroni-adjusted). In this instance,
399 if DIF was identified for multiple items in opposing directions, the DIF items would
400 be grouped into a subtest to explore if DIF would be cancelled out at test level (Andrich
401 & Hagquist, 2015). Additionally, the internal consistency of PARSC was assessed by
402 the person separation index (PSI), which can be interpreted in a similar way to a
403 Cronbach's α value. i.e. .60 -.69 - acceptable, .70 -.79 - sound, .80 -.89 -good and .90
404 or above – excellent) (Stevens, 2002).

405 SPSS for Windows 22 was used to generate descriptive statistics for the cohort
406 and to ascertain the test-retest reliability of PARSC and factors predictive of PA-
407 specific rumination tendencies. The revised scoring of PARSC would be used if Rasch
408 analysis indicated rescaling was called for. The data were first checked for univariate
409 and multivariate normality and outliers. Test-retest reliability was assessed by
410 intraclass correlation with 95% CI using a two-way random model (intraclass
411 correlation coefficient (ICC) $\geq .81$ = excellent, $.61-.80$ = good, $.41-.60$ = moderate
412 and $\leq .40$ = poor) (Nunnally & Bernstein, 1994). Multiple regression was performed
413 to evaluate the association between PA-specific rumination tendencies (dependent
414 variable) and objective PA level, self-reported PA level and avoidant coping
415 (independent variables). In total, 87 cases out of Sample 1 were included in the
416 regression analysis as they fulfilled the inclusion criteria for objective PA

417 measurement (see Procedure under Study 1 for objective PA measurement inclusion
418 criteria, and Table 1 for sample characteristics)¹.

419

420 **Results**

421 **Internal validity and internal consistency using Rasch analysis**

422 Original scale

423 For the original PARSC analysis, six well-distributed class intervals were
424 utilised ($n = 50-77$). Adequate overall fit of PARSC to the Rasch model is
425 demonstrated from the non-significant Chi-square probability value ($\chi^2 (50) = 58.41$,
426 $p = .19$). Fit residual values for all items were within ± 2.5 , suggesting good item fit.

427 A single person was identified with fit residual > 2.5 (indicating an unexpected response
428 pattern), and 24 people were identified with fit residual < -2.5 (indicating a predictable
429 response pattern). These people were retained within the analysis, as they were not
430 considered to be overly corrupting the analysis.

431 One pair of items, items 2 (How often do you think you might get hurt?) and 8
432 (How often do you think serious accidents may happen?), demonstrated local
433 dependency with a residual correlation of 0.12, > 0.2 compared to the mean of all
434 residual correlations. As the item set has no pre-existing clustering, the comparative
435 groups for the unidimensionality series of t-tests was determined through the
436 positively loading and negatively loading items from a principal component analysis
437 of the residuals. The series of t-tests reported that 3.93% of cases demonstrated
438 significant differences between the two comparative person estimates that were
439 generated. This suggests unidimensionality of the scale. Furthermore, DIF analyses

¹ Sample 2 did not complete the Children Coping Strategies Checklist nor PA measurements, they were thus excluded in the regression analysis (see Procedure under Study 2).

440 suggest that four items display DIF-by-sex, and three items display DIF-by-age group
441 (Bonferroni adjusted *p*-value > 0.05).

442 The person-item threshold distribution suggests that distribution of the person
443 estimates and item threshold was reasonably matched (or targeted) (mean ± sd person
444 logit = $-.59 \pm .89$, with average scale item mean = 0.00 logit), i.e., item difficulty could
445 adequately address the range of rumination tendencies (Figure 1a). Regarding the
446 response categories, disordered thresholds were evident for all items except item 4
447 (How often are you think you might feel ‘funny’ in your body, like in the tummy, in
448 the arms and legs, or feel ‘tired’?), indicating that the response scale is not working in
449 the expected manner for most items. Figure 2a illustrates the category probability
450 curve for item 6 as an example. This suggests that 4-response option appears too many
451 to be operational within this sample. Inspection of the person-item map indicates that
452 categories 2 and 3 (‘sometimes’ and ‘often’) appeared to be the most difficult to
453 endorse. Based on this information, a generic recode was applied across all items,
454 where categories 2 and 3 (‘sometimes’ and ‘often’) were treated as an equivalent
455 response, to deliver an implied 3-response category format.

456

457 --- *insert Figure 1a and 1b here* ---

458 --- *insert Figure 2a and 2b here* ---

459

460 *Revised scale after rescoreing*

461 After rescoreing, the class interval distribution was reviewed. Due to the uneven
462 distribution from 42-126 across the 6 intervals, we chose a 5-class interval structure
463 in order to reduce the variability between each class (57-94) before proceeding with
464 model fit analyses. The revised scale demonstrated good overall fit to the Rasch model

465 $(\chi^2 (40) = 52.36, p = .09)$. All individual items satisfied the model fit criteria. One
466 participant displayed a fit residual >2.5 (2.61), and 30 participants displayed fit
467 residuals < -2.5 . No local dependency was evident from the residual correlation matrix,
468 and the scale displayed (series of t-tests = 4.71%).

469 Rescoring of the response scale also saw more evenly distributed thresholds
470 (Figure 2b) and the person-item threshold map depicts adequate targeting between
471 item difficulty and person attributes (Figure 1b). DIF was still present for sex (items
472 1, 6 and 7 – Uniform DIF) and age group (items 1 and 5 – Uniform DIF). A subtest
473 was conducted for each person factor including the identified items, and analyses of
474 variance indicated that the DIF items cancelled each other out at test level ($p = .07$ and
475 $p = .11$ respectively), hence no further actions were taken to address the DIF issue.

476 Lastly, internal consistency of PARSC was deemed satisfactory with $\text{PSI} = .73$

477

478 **Test re-test reliability and predictive validity**

479 Utilising the logit (interval) scores of the revised PARSC from Sample 1 and
480 Sample 2, ICC coefficient suggested that the revised PARSC possessed sound test-
481 retest reliability ($\text{ICC} = .77$; 95% CI, .72 – .81). For predictive validity, avoidant
482 coping, objective and self-report PA level were entered as predictors. Results suggest
483 that PA rumination tendencies are predicted by self-reported PA ($\beta = .16, p = .003$;
484 95% CI, .04 - .25) and avoidant behavior ($\beta = .10, p = .02$; 95% CI, .02 - .19), but not
485 objective PA ($\beta = -8.31E, p = .36$), and 16% of the variance can be explained by the
486 model ($F(3, 83) = 5.00, p = .003$).

487

488 **Discussion**

489 In recent years, there is growing emphasis on the automatic implicit processes
490 that drive health behavior over and above the explicit processes that assume conscious
491 awareness, as automatic neurophysio-cognitive-affective responses can directly drive
492 our health decisions within split seconds (Sheeran et al., 2016). Oversight of the former
493 might be a key reason for the moderate effectiveness of PA behavior interventions
494 (Larsen & Holland, 2021). Essentially, rumination is a cognitive coping mechanism
495 that is closely linked to implicit cognition such as attention bias and affective processes
496 (Thayer et al., 2009). While rumination has shown to be a potential self-regulatory
497 mechanism that governs PA behavior, our understanding of this coping style in its
498 application to health behaviors is still in its infancy (Schlinkert & Koole, 2018;
499 Ottaviani et al., 2016). This is partly attributable to a lack of a psychometric instrument
500 to measure PA-specific rumination. Our study is the first to develop and validate a
501 rumination scale specific to PA behavior for school-aged UK children. PARSC with
502 a 3-point response scale has demonstrated sound internal validity, internal consistency
503 and test-retest reliability. PA-specific rumination tendencies were also found to be
504 negatively associated with self-reported PA and positively linked to avoidant coping.
505 Both findings are as expected – ruminators have the tendency to avoid stressors as it
506 could temper their heightened stress reactivity (Nolen-Hoeksema & Harrell, 2002;
507 Dickson et al., 2012), and the former finding resonates with existing literature (Riley
508 et al., 2019). However, it is surprising that objectively measured PA is not linked to
509 rumination tendencies. It is possible that the shrunken sample size in the analysis, due
510 largely to attrition/non-compliance from PA measurement (40%), failed to capture the
511 extreme ends of the PA spectrum while the possible underestimation of light-moderate
512 PA and overestimation of moderate-vigorous PA from the self-report might have
513 artificially inflated the variability (Sprengeler, et al., 2017). This level of attrition/non-

514 compliance is surprisingly larger than a previous report on similar measurement issues
515 in youth interventions (approximately 12% for attrition rate and 26% for non-
516 compliance rate; Howie & Straker, 2016). The smaller sample size has also
517 underpowered the predictive validity analysis by about 10%, based on β error
518 probability of 5%, through a posthoc power analysis. Future studies should consider
519 measuring objective PA in a larger sample to ascertain the predictive validity of
520 PARSC. Nonetheless, PARSC can be used to further our understanding of the role of
521 rumination in children's PA behavior. Future research can examine how PA-specific
522 rumination might link to other implicit processes such as attention bias and inhibitory
523 control from a neurocognitive perspective in order to provide a comprehensive
524 understanding of the neurophysiological-cognitive-affective self-regulatory
525 mechanisms that underpin PA behavior adaptation (Thayer et al., 2009).

526 As PARSC was developed through accounts of the lived experience of children
527 from the UK, it can be considered as a culture-specific instrument. Nonetheless, it can
528 potentially be used for other child populations. Findings from previous qualitative
529 studies on barriers of PA with Hispanic and Australian children are largely similar to
530 the themes identified in the current study, however, additional prominent themes from
531 the former include concerns about getting 'sweaty', and parent-driven rules such as
532 expectations of behavior indoor, and neither studies identified uncleanliness, sex
533 stereotype and lack of a sense of purpose from their participants (Ross & Francis, 2016;
534 Stanley et al., 2013). These discrepancies could potentially stem from cultural
535 differences, and from the fact that focus of these studies is less on the intrinsic barriers
536 but on environmental barriers as well. Therefore, if PARSC is used in children from
537 different cultural backgrounds, it is recommended that further validation process is in
538 place to ascertain its suitability.

539 For some of the intrinsic barriers that are relatively uncontrollable by
540 individuals, such as sex stereotype, uncleanliness, unfair play, previous negative
541 experiences and to some extent, injuries and accidents, it is important for researchers
542 and education professionals to help children overcome them by building resilience in
543 order to minimize their influence on children's PA. PA interventions can also consider
544 implementing strategies that address the other barriers through effective coaching. For
545 example, understanding that some children find the 'out of breath' experiences
546 disconcerting, PE sessions can focus on pacing strategies for a more even distribution
547 of effort intensity so that prolonged PA can be enjoyable, and at the same time,
548 awareness about this sensation can be raised as part of normal physiological
549 functioning so that children can reappraise the experience (Edwards & Polman, 2013).
550 Psychological interventions that aim to reduce stress response to PA, such as
551 mindfulness training, can also be implemented in order to promote PA adaptation
552 (Brown & Ryan, 2003). Intriguingly, when children expressed that a lack of purpose
553 being a barrier, they did not consider staying healthy as a purpose, yet, all agreed that
554 PA is a means to lead a healthy lifestyle. This certainly has implications on the content
555 of health messaging in PA interventions and public health campaigns, as focus on
556 health promotion is perhaps ineffective in motivating children to be active due to its
557 lack of relevance to children's value (Kreuter & Wray, 2003). Future research can also
558 explore the intrinsic motivators of PA, as incorporating these factors in public health
559 messages and PA interventions might enhance effectiveness in these initiatives.

560 A few limitations of the current study are worth noting. First, due to the limited
561 linguistic repertoire and self-reflexive ability, drawing in-depth information from the
562 youngest age group in focus group discussions was challenging. Focus group
563 discussions might not be the best way to understand the lived experience of children

564 under 7 years of age, instead, we might have to rely on reports from parents and
565 teachers who can explore children's in-the-moment PA experiences. Alternatively,
566 more creative approaches can be adopted, such as role play and using playdoh, if time
567 allows (Adler et al., 2019). Additionally, one group only consisted of two members
568 which might have limited potential discussions. Moreover, the psychometric
569 assessment led to a post-hoc rescaling of PARSC, and some DIF was indicated for
570 both sex and age groups. Although the post-hoc scoring appeared to work favourably,
571 and the impact of the DIF appeared to be small at the test level, this should be further
572 tested by a different sample in order to confirm the psychometric properties of the
573 PARSC, and to determine whether a 3-response category format is appropriate when
574 tested prospectively. Nonetheless, we consider the themes identified from the focus
575 group discussions and the phrasing of the items indicative of the construct in question,
576 future studies can lend support of construct validity through psychophysiological
577 response to PA-related stimuli with children of extreme ends of the PA spectrum.
578 Lastly, data of participants with physical/intellectual disabilities, or those who were
579 physically injured during the PA measurement period, have been excluded from
580 analysis as their habitual PA level and/or understanding of the questionnaire items
581 might be affected. Future studies should consider the inclusion of the data for analysis
582 in order to promote inclusivity.

583

584 **Conclusion**

585 To conclude, the current study has provided an in-depth understanding of the
586 culture-specific intrinsic barriers of PA in UK children which has contributed to the
587 development of PARSC. The psychometric properties of PARSC were also confirmed.
588 Through PARSC, we can advance our understanding of rumination as a self-regulatory

589 coping mechanism that underpins PA behavior adaptation in young children. It is also
590 imperative that state rumination tendencies are identified at an early age, due to its
591 potential to develop into a trait-like cognition which can adversely affect mental health.
592 Moreover, we encourage researchers and public health professionals to consider our
593 qualitative findings in the design of future PA interventions and health messaging for
594 this population. Additionally, education professionals can implement interventions
595 such as resilience training and mindfulness training to effectively promote PA to
596 young children with relatively high PA rumination tendencies as identified through
597 PARSC.

598

599 **What does this article add?**

600 Physical activity interventions for children have demonstrated limited effectiveness
601 to promote physical activity, possibly because automatic implicit processes that may
602 directly hinder behavior adaptation have been largely overlooked. The mechanistic
603 process of interest in this study is physical activity-specific rumination, defined as
604 the tendency to engage in repetitive negative thoughts about physical activity. To
605 date, we have limited understanding of the link between rumination and physical
606 activity behavior in children, despite that rumination has been studied in other health
607 behaviors. In this study, we have developed the Physical Activity-specific
608 Rumination Scale for Children (PARSC) through exploring factors that intrinsically
609 demotivate (intrinsic barriers) school-aged UK children from engaging in physical
610 activity. PARSC has demonstrated sound psychometric properties. This is the first
611 study to develop and test an instrument that measures physical activity-specific
612 rumination tendencies, and to provide intrinsic barriers that are culturally relevant.
613 Not only will the questionnaire further our understanding of the role of rumination in

- 614 children's physical activity behavior, crucially, it can be used to identify children
615 with physical activity rumination tendencies and implement interventions to promote
616 long-term physical activity participation and mental health.

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618 Please refer to the information provided in the Title Page.

619

620 **ORCID**

621 Please refer to the information provided in the Title Page.

622

623 **Disclosure statement**

624 The authors declare no conflicts of interest.

625

626 **Data availability statement**

627 The data that support the findings of this study are available from the corresponding

628 author upon reasonable request.

629

630 **Author Contributions**

631 The study was conceived by the first author who also collected and analysed data for

632 both studies. The second author co-analysed the qualitative data and the third author

633 co-analysed the quantitative data. All authors contributed to manuscript preparation.

634

635 **Disclosure**

636 The authors declare no conflicts of interest.

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