Title:

High-intensity demands of 6-a-side small-sided games and 11-a-side matches in youth soccer

players

Running title:

Small-sided games and matches in youth soccer

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1   **ABSTRACT**

2   **Purpose.** The purposes of the present study were to examine: high-intensity running distance

3   during 6-a-side small-sided games (SSGs) and 11-a-side matches (11M) in youth soccer

4   players using speed and metabolic power approaches and; the magnitude of difference

5   between high-intensity running distance calculated with the two approaches. **Method.** Eleven

6   outfield players (age = 16.3 ± 0.6 years) performed SSGs with three pitch sizes (small SSG

7   (SSGS), medium SSG (SSGM) and large SSG (SSGL)) and 11M. A Global Positioning

8   System (15 Hz) was employed to calculate total distance covered, distance covered at a speed

9   ≥ 4.3 m·s^{-1} (TS) and metabolic power of ≥ 20 W·kg^{-1} (TP). **Results.** The total distance

10   covered increased from SSGS through to SSGL ($P < 0.001$) and was greater during 11M and

11   SSGL compared to other SSGs ($P < 0.01$). TS and TP increased from SSGS (TS vs. TP = 98 ±

12   55 vs. 547 ± 181 m) through to SSGL (538 ± 167 vs. 1050 ± 234 m, $P < 0.001$). TS and TP

13   during 11M (370 ± 122 vs. 869 ± 233 m) was greater than SSGS ($P < 0.001$ for both) and less

14   than SSGL ($P < 0.05$ for both). The magnitude of difference between TS and TP (%) reduced

15   with an increase in pitch size during SSGs and was greater in SSGS (615 ± 404%, $P < 0.001$)

16   and SSGM (195 ± 76%, $P < 0.05$) and smaller in SSGL (102 ± 33%, $P < 0.01$) compared to

17   11M (145 ± 53%). **Conclusion.** SSGs can replicate the high-intensity demands of 11M and

18   the speed approach underestimates high-intensity demands of SSGs and 11M compared to the

19   metabolic power approach.

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INTRODUCTION

Small-sided games (SSGs) have been commonly used as a training drill by coaches to develop physical fitness (21,25,35) or technical and tactical abilities (27,32,36) of soccer players. Many studies have investigated the variables which influence the physical demands during SSGs (23) and such variables include pitch size (area per player) (7,34), player number (1,3,22,), coach feedback (2,34), training regimen (continuous or interval) (9,24), rule modifications (20), use of goals and/or goalkeepers (10) and prior knowledge of exercise duration (12). Hence, many elements must be considered to control the physical demands during SSGs.

The identification of training modalities which most closely replicate the physical demands of soccer match play is of great interest to coaches and exercise scientists who are concerned with optimizing training stimuli (8,34). To date, only three studies have compared the demands of SSGs and 11-a-side matches (11M) (8,13,28). Unfortunately, within each of these previous studies more than one game-related variable has been manipulated (e.g. player number and pitch size) making it impossible to isolate the independent effect of either. Furthermore, each of these previous studies examined adult participants, and it is recognized that players in the developing stages should not be considered as miniature adults (37). It is therefore necessary to examine the differences in the physical demands between SSGs and 11M in young soccer players whilst modifying only one variable to investigate the specific format of SSGs which mimic the physical demands of 11M.

 In recent years, the metabolic power approach has been employed to examine the physical demands of training sessions (15), SSGs (14,39) and match play (33) in elite professional soccer players; with a common use of Global Positioning Systems (GPS) for data collection

49   (14,15). Metabolic power is obtained by multiplying the estimated energy cost of

50   accelerated/decelerated running on a horizontal level with an assumption that

51   accelerated/decelerated running on a horizontal level is energetically equivalent to

52   uphill/downhill running at a constant speed on an 'equivalent' slope. As energy costs are

53   independent of the velocity and the energetics of uphill/downhill running can be described, an

54   estimation of the energy costs of accelerated/decelerated running on a horizontal level can be

55   achieved (33). The metabolic power approach involves accelerations and decelerations

56   whereas the traditional speed approach only includes distances covered at constant speeds.

57   The latter neglects the importance of accelerations and decelerations when estimating

58   metabolic demands (33). Accelerations are a pre-cursor to running at high speeds and during

59   accelerations, a greater neural activation to the working muscles and a higher rate of force

60   production are required compared to a constant speed running (29,33). Even when moving at

61   low speeds, a great amount of metabolic load is imposed on soccer players when acceleration

62   is raised, and decelerations occur as frequently as accelerations in soccer that each

63   significantly contribute to the physical demands of soccer (33). Moreover, the metabolic

64   power approach is more strongly related to energy expenditure compared to the traditional

65   speed approach (5,19).

66

67   The high-intensity demands during SSGs (14) and match-play (33) have previously been

68   examined with speed and metabolic power approaches in professional soccer players. The

69   previous study employed 5-a-side, 7-a-side and 10-a-side SSGs with area per player of 75, 98

70   and 135 m^2, respectively (14). The results showed increases in high-intensity running distance

71   with increases in player number and area per player in both approaches. Moreover, the high-

72   intensity running distance of SSGs were underestimated by the speed approach compared to

73   the metabolic power approach by around 45-350% and the underestimation was greater when

74   the area per player was reduced (14). In addition, the speed approach underestimated the high-

75   intensity running distance during a match by ~45% in professional soccer players compared to

76   the metabolic power approach (33). Although the high-intensity demands of SSGs and 11M

77   have been investigated in the separate studies using two approaches (speed vs metabolic

78   power), from the authors' knowledge, such variables have not been examined in a single

79   study with the same participants (14,33,39). Furthermore, metabolic power related data on

80   SSGs and 11M is only available on senior and elite youth players (14,33,39). Since

81   physiological and physical responses during SSGs and 11M differs depending on standard of

82   play (30,39), an investigation of the high-intensity demands of SSGs and 11M using two

83   approaches (speed vs metabolic power) in non-elite youth players would provide a greater

84   understanding of relationships between the two approaches (speed vs metabolic power)

85   during SSGs and 11M in this particular category of players. Such investigation would support

86   coaches and sports scientists to provide group specific training programs and maximize

87   performance enhancement.

88

89   Therefore, the aims of the present study were to examine: 1) the high-intensity demands of

90   SSGs and 11M in youth soccer players using two approaches (speed vs metabolic power) and:

91   2) the magnitude of difference between running distance calculated with speed and metabolic

92   power approaches during SSGs and 11M.

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95   **METHOD**

96   **Participants**

97   The subjects were 11 outfield players from the same soccer team who competed in regional

98   level competitions (age = 16.3 ± 0.6 years; height = 170.1 ± 6.4 cm; body mass = 59.8 ± 7.5

99   kg; playing experience = 6.1 ± 1.3 years; 10 m sprint time = 1.74 ± 0.08 s; Yo-Yo intermittent

100   recovery test level 1 = 1316 ± 289 m). The team trained five times and played one match per

101   week on average during a season and all training involved technical based sessions. Subjects

102   were provided with a written and verbal explanation of the study including experimental

103   protocols and all measurements to be taken. Each player signed an informed assent form and

104   completed a health screen questionnaire prior to participation in the study. Each player's

105   parent signed a consent form prior to the start of the study. Players were free to withdraw

106   from the study without giving any reasons. The study was approved by a University Ethical

107   Committee.

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109   **6-a-side small-sided games and 11-a-side matches**

110   The participants performed 6-a-side SSGs (five field players and a goalkeeper) with three

111   different pitch sizes (small SSG (SSGS), medium SSG (SSGM), large SSG (SSGL)) and 11M

112   as part of training sessions. Established characteristics of SSGs and 11M are shown in table 1

113   and all SSGs and 11M employed the same pitch length to width ratio. In SSGs, each team

114   contained two central defenders, a defensive midfielder, a central attacking midfielder and a

115   striker. A playing system of 4-2-3-1 was only allowed during 11M. Participants played their

116   natural playing positions during SSGs and 11M. The players included in each team were

117   generally fixed for all SSGs and 11M but there was a maximum of one player difference in a

118   team in some sessions due to injuries or unavailability. The players in each team were

119   selected by the coach who was asked to include players with similar ability to balance the

120   strength of the teams.

121

122   All data collection took place on the same pitch which was a third generation synthetic

123   astroturf (Grand Grass F-M DS, Mizuno corporation, Osaka, Japan). Laws of the game (40)

124   were applied during SSGs and 11M but the offside rule was neglected during SSGs. Each of

125   the SSGs and 11M were conducted four times during six weeks and two to three sessions took

126   place in each week. They were conducted in a counterbalanced order and the day after a

127   match was avoided. All participants took part in each of the SSGs and 11M for 2.7 ± 0.8 times

128   (range = 2-4 times). Each session started with the same warm-up from 15:00 (approximately

129   30 minutes) which involved static and dynamic stretches, running at various speeds from

130   jogging to sprinting and technical drills. The duration of all SSGs and 11M was 35 minutes

131   because that was the duration of a half of participants' official matches. A multi-ball system

132   was employed to minimise non-playing time and similar verbal encouragement was given by

133   the coach during SSGs and 11M as coaches' feedback can influence physical demands (2,34).

134   The environmental temperature was between 24 and 28 ℃ and humidity between 63 and 85%

135   during the data collections (rainy days were avoided).

136

137   ---------------- Table 1 here ------------------

138

139   **Physical demands**

140   The previously reported equation has been employed to estimate metabolic power and

141   assumed energy cost of running at constant speed was 3.6 $J\cdot kg^{-1}\cdot m^{-1}$ (33).

142

143   Metabolic power = EC · v

144

145   Where, EC = the energy cost of accelerated running on grass ($J \cdot kg^{-1} \cdot m^{-1}$) = ($155.4 \cdot ES^5 -$

146       $30.4 \cdot ES^4 - 43.3 \cdot ES^3 + 46.3 \cdot ES^2 + 19.5 \cdot ES + 3.6) \cdot EM \cdot KT$, ES = the equivalent slope = tan (90

147       $-$ arctan g/a_f), g = Earth's acceleration of gravity; a_f = forward acceleration; EM = the

148   equivalent body mass = $[(a_f^2 \cdot g^{-2}) + 1]^{0.5}$, KT = a constant = 1.29, v = running speed ($m \cdot s^{-1}$).

149

150   In addition to total distance covered, high-intensity physical demands were analysed with the

151   assessment of speed and metabolic power. The distance covered at a speed ≥ 4.3 $m \cdot s^{-1}$ (TS)

152   (33) and metabolic power of ≥ 20 $W \cdot kg^{-1}$ (TP) (14,15) were calculated. These values were

153   chosen because 20 $W \cdot kg^{-1}$ is the metabolic power when running at a constant speed of

154   approximately 4.3 $m \cdot s^{-1}$ on natural (33) and artificial (38) grass. Physical demands were

155   analysed with 15 Hz (5 Hz signal interpolated to 15 Hz) GPS technology (SPI HPU,

156   GPSports, Canberra, Australia) which was positioned on the upper back in a custom-made

157   vest. This particular device has been reported to possess less than 1% error in estimating the

158   total distance covered when 8 laps of a team sport simulation circuit (165 m) was completed.

159   The circuit included resting, different type of movements (straight walking/running, figure

160   eight agility run, 90 degrees turning), various speeds (walking to sprinting) and fast

161   accelerations/decelerations (26). Moreover, there was a <5% difference in maximal speed

162   during 30 m sprint with split times at 10 and 20 m between the values estimated using GPS

163   and photoelectric timing gates (26). Moreover, inter-unit reliability (percentage typical error

164   of measurement) for total distance covered, distance covered at < 3.9 $m \cdot s^{-1}$, 3.9-5.6 $m \cdot s^{-1}$ and

165   >5.6 $m \cdot s^{-1}$ were 1.9, 2.0, 7.6 and 12.1%, respectively (26). At least 8 satellites (mean $\pm$ SD =

166   9.5 ± 0.8 satellites) were connected during data collection which is the minimum number of

167   satellites required to allow an accurate measurement (41,42) and mean horizontal dilution of

168   position was 1.2 ± 0.2 during data collections. Total distance covered, TS and TP were

169   calculated using Team AMS software version R1.2016.4 (GPSports, Canberra, Australia) and

170   the software filtered through all data concerning velocity, acceleration and deceleration to

171   eliminate noise before calculating the distance.

172   **Statistical analyses**

173   The mean values from SSGs and 11M for each player were calculated before calculating

174   group means and conducting the statistical analyses. The magnitude of difference was

175   calculated by dividing an absolute difference between TS and TP by TS and multiplied by

176   100. Data were normally distributed as examined by a Kolmogorov-Smirnov test. Levene's

177   Test revealed that variances were unequal for SSGs and 11M. Hence, one-way analysis of

178   variance with Games-Howell post hoc test was employed to compare physical demands

179   between 11M and SSGs. The effect size (η^2) was calculated and values of 0.01, 0.06 and

180   above 0.15 were considered as small, medium and large, respectively (11). Levene's Test

181   revealed that variances were equal for TS and TP in each of the SSGs and 11M therefore an

182   independent sample t-test was employed to assess whether or not there were statistically

183   significant differences between TS and TP. The effect sizes (*d*) for these differences were

184   calculated as (mean A – mean B)/ (pooled SD) and values of 0.2, 0.5 and above 0.8 were

185   considered to represent small, moderate and large differences, respectively (11). The level of

186   statistical significance was set at $p < 0.05$. Results are presented as mean ± standard deviation

187   (SD) and IBM SPSS 22.0 was used for all the statistical analyses.

188   **RESULTS**

189   **Comparison of physical demands between SSGs**

190   Total distance covered, TS and TP increased from SSGS through to SSGL (P < 0.001 for all,

191   η^2 = 0.44-0.65) (figure 1-3).

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193   ------------------------ Figure 1 to 3 here ------------------------

194

195   **Comparison of physical demands between SSGs and 11M**

196   The total distance covered during 11M was similar to SSGL and greater than SSGS and

197   SSGM (P < 0.001 for all, η^2 = 0.58) (figure 1). TS during 11M was approximately four times

198   greater than SSGS (P < 0.001) and ~45% less than SSGL (P < 0.001) (η^2 = 0.65) (figure 2).

199   TP during 11M was ~59% greater than SSGS (P < 0.001) and ~21% less than SSGL (P <

200   0.05) (η^2 = 0.44) (figure 3).

201   **Difference between TS and TP**

202   TP was greater than TS in all SSGs and 11M (~450 to ~520 m, P < 0.001, d = 1.3-1.9 for all)

203   (figure 2 and 3). The magnitude of difference between TS and TP (%) reduced with an

204   increase in pitch size from ~620% for SSGS to ~100% for SSGL (P < 0.001, η^2 = 0.51)

205   (figure 4). Moreover, the magnitude of difference between TS and TP (%) in 11M was greater

206   than SSGL (P < 0.01) and less than SSGS (P < 0.001) and SSGM (P < 0.05) (η^2 = 0.51)

207   (figure 4).

208

209   -------------------- Figure 4 here ----------------------

210

211 **DISCUSSION**

212 This is the first study that examined the high-intensity demands of 6-a-side SSGs (three

213 different pitch sizes) and 11M using speed and metabolic power approaches in youth soccer

214 players. The main findings of the present study were that: 1) the high-intensity demands of 6-

215 a-side SSGs increased when the pitch size was enlarged regardless of approaches (speed vs

216 metabolic power); 2) TS and TP during 11M and SSGM were similar; 3) the speed approach

217 underestimated the high-intensity demands of 6-a-side SSGs and 11M compared to the

218 metabolic power approach; 4) the underestimation of high-intensity demands during SSGs

219 increased with a reduction in pitch size; and 5) the underestimation of high-intensity demands

220 during 11M was less than SSGM.

221

222 The first major finding of the current study was that total distance covered, TS and TP during

223 6-a-side SSGs, increased when pitch size was expanded. For total distance covered, a

224 previous study of 15-year-old boys during 6-a-side SSGs agreed with the current findings (7).

225 However, the previous study reported that TS was only greater in medium and large

226 compared to small pitch size with no differences between medium and large pitches (7). This

227 disagreement is possibly because the previous study employed a smaller pitch size ratio

228 between medium and large SSGs compared to the current study (medium: large = current, 1: 2

229 vs previous, 1: 1.5) (7). Moreover, similar findings to the current study in TP have been

230 demonstrated in professional soccer players when player number and area per player were

231 increased together (14).

232

233 The total distance covered during SSGL and 11M in the current study was similar to the

234 previous studies. The current participants covered ~4000 m during 11M and when the

235 distance was adjusted to match playing time, the distance was consistent with under-16 soccer

236   players from England (16,18) and Qatar (6). Moreover, the distance covered during 11M was

237   similar to SSGL which suggests that total distance does not differ when player number

238   changes as long as the area per player is the same. However, the previous studies reported that

239   a change in player number influences (22) or does not influence (1) total distance and total

240   distance is a poor indicator of global work rate in SSGs (22) and 11M (30).

241

242   The second major finding of the current study was that TS and TP during 11M were greater

243   than SSGS, less than SSGL and similar to SSGM. A previous study which examined the

244   physical demands of 6-a-side SSGs and 11M in semi-professional soccer players concluded

245   that SSGs are played at a higher intensity than 11M when area per player of SSGs was two-

246   thirds of 11M (SSG vs 11M = 200 vs 300 m^2) (8). Conversely, the area per player of SSGM

247   was roughly half of 11M in the current study (SSGM vs 11M = 165 vs 325 m^2). These

248   findings suggest that 6-a-side SSGs with roughly half the area per player of 11M provides a

249   similar high-intensity demand to 11M; whereas 6-a-side SSGs with around two-thirds and

250   greater area per player of 11M offer a greater high-intensity demand than 11M. In addition,

251   players perform less high-intensity running during 6-a-side SSGs than 11M when area per

252   player of SSGs is approximately a quarter of 11M.

253

254   The third major finding of the current study was that TP was greater than TS during all SSGs

255   and 11M. Similar findings have been reported during various SSGs (14,39), 11M (33) and

256   training sessions (15). In the current study, the magnitude of difference between TS and TP

257   during SSGs were ~100 to ~620% and that was reduced with pitch size from SSGS through

258   SSGL. Similar values (~20% to ~349%) (14,39) and a trend (14) have been observed in the

259   previous studies on SSGs. However, the previous study modified player number and area per

260   player together (14) and the current study is the first to demonstrate that a modification of

261   area per player alone still alters the same relationship between area per player and magnitude

262   of difference between TS and TP in SSGs. The variations in the underestimation of high-

263   intensity demands in SSGs exists because players are required to produce a greater or lesser

264   proportion of high-intensity activities at constant high speeds depending on pitch size of SSGs

265   and that results in decreases or increases in the production of explosive accelerations and

266   decelerations (14,15). Although the metabolic power approach reflects metabolic internal

267   loads, and running distance calculated by the speed approach demonstrates external loads, the

268   employment of the metabolic power approach probably offers a more valid indication of the

269   high-intensity demands of SSGs and 11M in youth soccer player as metabolic power approach

270   includes demands of accelerations/decelerations (14).

271

272   A further major outcome of the current study was that the magnitude of difference between

273   TS and TP during 11M was ~145%. This value seems to be greater than the magnitude of

274   difference reported from match play of professional soccer players (~45%) (33). The

275   professional players covered a greater proportion of total match distance by high-intensity

276   running (current vs professional: 4.3 $m·s^{-1}$ vs 4.4 $m·s^{-1}$) compared to the participants in the

277   current study (current vs professional: 9% vs 18%) (33) which suggests that the professional

278   players produced a larger proportion of high-intensity activities at constant high speeds and a

279   less amount of explosive accelerations and decelerations at low speeds compared to the

280   participants of current study (14,15). Hence, the speed approach underestimates high-intensity

281   demands of match play compared to metabolic power approach especially in the players who

282   covers less distance with high speeds.

283

284   Given that TS and TP did not differ between SSGM and 11M in the current study, the

285   magnitude of difference between TS and TP was greater during SSGM compared 11M. The

286 rationale for this finding is unknown but modification of player number alone has been shown

287 to influence demands of SSGs including heart rate (1,3,22) and running distance (1,22) related

288 variables that different number of players employed in SSGM and 11M may explain the

289 current result. The current study mainly focused on the influence of pitch size modification on

290 physical demands during SSGs with a fixed player number and future studies should

291 investigate the influence of player number on high-intensity demands and the underestimation

292 of speed approach compared to metabolic power approach.

293

294 There are three possible limitations to the current study. Firstly, the current study compared

295 the high-intensity demands of SSGs and 11M with a playing time of 35 minutes in all

296 sessions. However, a single bout of SSGs is traditionally much shorter than the duration

297 employed in the current study (3-8 minutes) (17) and longer duration would reduce distance

298 covered in high speeds and frequency of high intensity activities (24). Hence, it is important

299 to note that an employment of SSGs with a different duration to the current study may result

300 in players showing different physical responses. Secondly, the current study could not include

301 heart rate (HR) in the analysis due to having invalid HR data in many occasions. HR data may

302 have supported the analysis by providing physiological loads which is different to

303 displacement measures. Finally, the current study did not control tactical aspects of SSGs and

304 11M. Although tactical differences can influence physical responses during SSGs (31) and

305 11M (4), this is an under researched area that such aspects may need to be explored further in

306 the future research.

307

308

309   **CONCLUSION**

310   The current findings demonstrate that 6-a-side SSGs can replicate the high-intensity demands

311   of 11M in youth soccer players when the area per player of the SSGs is approximately half of

312   11M. On the other hand, two-thirds or greater area per player of 11M provides a greater high-

313   intensity demand during 6-a-side SSGs and a quarter of the area per player of 11M would

314   require less high-intensity demand during 6-a-side SSGs compared to 11M. Moreover, total

315   distance covered and high-intensity running distance during 6-a-side SSGs increase with

316   enlargement of pitch size regardless of approach (speed vs metabolic power). However, the

317   speed approach underestimates the high-intensity demands of SSGs and 11M compared to the

318   metabolic power approach; and the underestimation increases exponentially with a reduction

319   in pitch size in SSGs. Therefore, coaches and sports scientists should pay attention to

320   methodology for monitoring players (speed vs metabolic power) and are advised to carefully

321   choose pitch size of SSGs together with number of players per team depending on the aim of

322   training sessions.

323

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436 **FIGURE LEGENDS**

437 Figure 1. Total distance covered during SSGs and 11M. Significantly different at *p < 0.05

438 **P < 0.01. ***P < 0.001. SSGS = small small-sided game; SSGM = medium small-sided

439 game; SSGL = Large small-sided game; 11M = 11-a-side match.

440

441 Figure 2. TS during SSGs and 11M. Significantly different at *p < 0.05 **P < 0.01. ***P <

442 0.001. SSGS = small small-sided game; SSGM = medium small-sided game; SSGL = Large

443 small-sided game; 11M = 11-a-side match, TS = distance covered at a speed $\geq$ 4.3 m·s^{-1}.

444

445 Figure 3. TP during SSGs and 11M. Significantly different at *p < 0.05 **P < 0.01. ***P <

446 0.001. SSGS = small small-sided game; SSGM = medium small-sided game; SSGL = Large

447 small-sided game; 11M = 11-a-side match, TP = distance covered at metabolic power of $\geq$ 20

448 W·kg^{-1}.

449

450 Figure 4. Magnitude of difference between TS and TP in SSGs and 11M. Significantly

451 different at *p < 0.05 **P < 0.01. ***P < 0.001. SSGS = small small-sided game; SSGM =

452 medium small-sided game; SSGL = Large small-sided game; 11M = 11-a-side match, TS =

453 distance covered at a speed $\geq$ 4.3 m·s^{-1}, TP = distance covered at metabolic power of $\geq$ 20

454 W·kg^{-1}.

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459 **TABLES**

Table 1. Established characteristics of SSGs and 11M.

	SSGS	SSGM	SSGL	11M
Pitch length (m)	39	55	78	105
Pitch width (m)	25	36	50	68
Playing area (m^2)	975	1980	3900	7140
Area per player (m^2)	81	165	325	325
Duration (min)	35	35	35	35
Goalkeepers	Yes	Yes	Yes	Yes
Offside rule	No	No	No	Yes

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Figure 1

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Figure 2

Figure 3

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Figure 4