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Usefulness of an auditory aid to improve chest compression rate accuracy during cardiopulmonary resuscitation

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1 **Abstract**

2 **Objective** – To assess compression rate accuracy amongst veterinarians and registered veterinary
3 nurses (RVNs) without and with an audible aid.

4 **Design** – Prospective study with use of a canine CPR manikin.

5 **Setting** – Quiet room in small animal hospital.

6 **Subjects** – 36 participants (20 veterinarians and 16 RVNs).

7 **Interventions** – Each participant completed the first two-minute cycle of chest compressions without
8 an auditory aid on a canine CPR manikin. Each participant was then randomized to one of three
9 auditory aid groups (Group B: Bee Gees ‘Stayin’ Alive’; Group Q: Queen ‘Another One Bites the Dust’
10 or Group M: Traditional metronome) and then completed a second two-minute cycle of chest
11 compressions with the instruction to synchronize their compression rate with the beat of the
12 auditory aid. An accurate chest compression rate was defined as obtaining a rate between 100-120
13 compressions per minute (cpm).

14 **Measurements and Main Results** – Median cpm administered by participants during Cycle 1 for the
15 1st minute was 111 (range 88-140) and for the 2nd minute was 107 (range 80-151), with 25/36 (69%)
16 participants obtaining an accurate chest compression rate. Median cpm administered during Cycle 2
17 for the 1st minute was 110 (range 76-125) and for the 2nd minute was 110 (range 72-125), with 34/36
18 participants (94%) obtaining an accurate chest compression rate. Participants were more likely to
19 obtain an accurate chest compression rate when an auditory aid was present compared to without
20 (McNemar’s test; $p=0.013$). Subgroup analysis suggested the auditory aid was beneficial in Group Q
21 and M but not Group B (Kruskal Wallis with Dunn’s post-hoc testing; $p=0.014$, $p=0.0455$ and
22 $p=0.5637$, respectively).

23 **Conclusions** – An auditory aid was associated with improved chest compression rate accuracy.
24 However, as the auditory aid was not beneficial for Group B participants, our findings suggest that
25 some some auditory aids are more helpful than others.

26

27

28 **Abbreviations**

29 cpm: compressions per minute

30 CPR: cardiopulmonary resuscitation

31 RECOVER: Reassessment Campaign on Veterinary Resuscitation

32 ROSC: return of spontaneous circulation

33 RVNs: registered veterinary nurses

34 Introduction

35 Basic life support encompasses recognition of cardiopulmonary arrest, delivery of chest
36 compressions and airway management with provision of ventilation.¹⁻³ The quality of basic life
37 support is associated with return of spontaneous circulation (ROSC) and survival in numerous
38 studies.⁴⁻⁶

39
40 Appropriate chest compression technique is the cornerstone of high-quality
41 cardiopulmonary resuscitation (CPR).^{1-3,7} This requires that all clinical team members have a
42 theoretical knowledge and complete regular training for development of the necessary psychomotor
43 skills for optimal performance.⁸ Chest compressions are optimized by appropriate hand position,
44 compression rate, compression depth and chest wall recoil.^{1-3,7} Current CPR guidelines advise a
45 compression rate of 100-120 compressions per minute (cpm), based on a high-quality experimental
46 canine study which identified that a compression rate of 120 cpm was associated with a higher rate
47 of ROSC and 24-hour survival compared to a compression rate of 60 cpm.^{1-3,7}

48
49 Despite increasing awareness of recommended compression rates during CPR, these may be
50 difficult to achieve in reality. A clinical observational study of human cardiac arrest patients reported
51 a compression rate compliance of only 28%.⁹ A study assessing the ability of veterinary students
52 without prior CPR experience to deliver a compression rate of 100 cpm on a canine manikin found
53 that 53% of participants were successful.¹⁰ A clinical study by Hoehne et al. documented a
54 compression rate compliance of 76% in a prospective study involving 219 CPR events.¹¹ This study
55 reported cpm administered by veterinarians in practice but the study was not specifically focused on
56 assessing chest compression rate adequacy, limited further by compression rates being self-reported
57 and not objectively measured. Additionally, the clinical nature of the study meant that no members
58 of the resuscitation team underwent formal training within a predefined time frame of the CPR
59 events occurring.

60

61 One method to improve compression rate accuracy during CPR is to use an auditory aid for
62 guidance.^{8-10,12-20} The auditory aid provides a tempo for compression rate administration and has
63 been shown to improve compression rate accuracy when used during training and clinical practice of
64 both lay persons and human medical personnel.^{8-10, 12-20} Additionally, auditory aids have been found
65 to help prevent deterioration of chest compression rate associated with fatigue over time.^{8,12,15}

66

67 A traditional metronome is a low-cost and readily available device, which may be used as an
68 auditory aid.^{9,14,16,18,21} The traditional metronome produces clear beats set at a specific rate as
69 determined by the operator with the rescuer instructed to deliver compressions at the same rate to
70 that of the metronome. Alternatively, several popular songs with beat counts between 100-120 per
71 minute may be used as an auditory aid with the beat of the song providing a cadence for
72 compression rate administration by rescuers.^{8-10,12-20,22} Human guidelines are supportive for the use
73 of auditory guidance during CPR to aid adherence and delivery of high-quality CPR, however, at
74 present, there is no consensus, on the optimal auditory aid rate, type, and if using a popular song, it
75 is unknown which is preferred.^{2,23}

76

77 Popular songs with beat counts between 100-120 per minute can inspire recall for the rate
78 of compressions, even when not audible.^{8,10,15,22,24} Rescuers can think of these songs whilst delivering
79 compressions to aid compression rate accuracy. In this capacity, the popular song acts as a mental
80 metronome. A study evaluating the utility of a song as a mental metronome concluded that
81 veterinary students were more likely to achieve an appropriate compression rate when using a
82 mental metronome compared to veterinary students who were only instructed to administer chest
83 compressions at a rate of 100 beats per minute.¹⁰ To the author's knowledge, this is the only study
84 assessing the utility of an auditory aid (traditional metronome or popular song audible or as mental
85 metronome) within the veterinary literature. At present, it is unknown if chest compression rate

86 accuracy is improved with the use of an auditory aid by veterinary clinical members and hence the
87 current Reassessment Campaign on Veterinary Resuscitation (RECOVER) guidelines make no
88 recommendation relating to their use in CPR. The aim of this study was to assess compression rate
89 accuracy amongst veterinarians and registered veterinary nurses (RVNs) without and with an audible
90 aid (music or traditional metronome). A secondary aim was to assess the frequency and utility of use
91 of a mental metronome to aid rate of chest compressions by veterinarians and RVNs. We
92 hypothesized that the use of an audible aid would increase compression rate accuracy but there
93 would be no significant difference between the use of a music or traditional metronome.

94 **Materials and Method**

95 The study protocol was approved by the institution's Veterinary Ethical Review Committee.
96 All veterinarians and RVNs working within the small animal teaching hospital were eligible for study
97 inclusion. Participants were recruited on a voluntary and informed basis via an email sent to hospital
98 staff. Each interested individual was asked to sign a consent form for participation and then asked to
99 attend one session based on their convenience. Each participant enrolled was allocated to one 30
100 minutes slot, with 4 participants enrolled in each 2-hour session. Each participant was evaluated on
101 a 1:1 basis, with only one study participant and one study investigator present at any one time
102 during a session. The sessions took place in a quiet room, away from clinical activities, in the small
103 animal hospital.

104
105 There were three auditory aid study groups. Group B utilized the music aid Bee Gees,
106 "Stayin' Alive" (103 beats per minute), Group Q utilized the music aid Queen, "Another one bites
107 the dust" (110 beats per minute) and Group M utilized a traditional metronome set at a rate of 110
108 beeps per minute from a smart phone app.^a For Group B and Group Q, a 2-minute clip of each song
109 was made to ensure that each participant heard the same clip of the song.

110
111 A 5-minute video was developed by the study investigators to demonstrate how to perform
112 optimal chest compressions using a canine manikin.^b This video demonstrated optimal hand
113 placement, locking of elbows, patient positioning, chest compression rate and importance of chest
114 wall recoil. An optimal compression rate of 100-120 cpm was advised based on current RECOVER
115 guidelines.⁷ Optimal compression depth was not emphasized given the difficulty in achieving this on
116 a manikin. All participants performed chest compressions on the same manikin^b as used in the video.
117 Each participant watched the video at the start of their session and then had the opportunity to
118 practice chest compressions (up to 10 minutes) before initiating the first cycle (Cycle 1) of studied
119 CPR. Participants did not receive feedback from a study investigator on their practice chest

120 compressions. If a participant did want to practice their compressions, a 5-minute break between
121 practice and Cycle 1 of chest compressions was given.

122

123 **Cycle 1**

124 Participants were asked to perform 2 minutes' worth of chest compressions on the CPR
125 canine manikin^b as described within the video without an auditory aid. The manikin^b was positioned
126 in lateral recumbency on a table which could be height adjusted. Each participant was instructed to
127 assess the table height and adjust as necessary prior to starting compressions. A camera was used to
128 record participant efforts for data quality assurance. Only one study investigator was present, being
129 responsible for video recording, timing the 2-minute cycle with a stopwatch and communicating the
130 start and end time of the 2-minute period to each study participant. The video recording was started
131 prior to the start of the cycle and stopped after the end of the cycle. No study investigator counted
132 the number of compressions live during the cycle and all evaluations were based on the video
133 recordings.

134

135 **Questionnaire and Group Assignment**

136 During recovery, each participant was asked to complete a 5-minute questionnaire, which
137 had questions relating to participant demographics, frequency each participant performed CPR, date
138 of last CPR training and whether they had completed any RECOVER CPR training. Each participant
139 was also asked whether they used a mental metronome during Cycle 1, and if they did, they were
140 asked to state the mental metronome used. Each participant was then informed of their study
141 group allocation and had the opportunity to have 10 minutes to practice their chest compressions
142 based on their group assignment. Participants were instructed to synchronize their compressions
143 with the beat of the auditory aid. Each auditory aid was played from a tablet at a 2-meter distance
144 away from the manikin^b and at the same volume each time.

145

146 **Cycle 2**

147 Each participant was asked to complete a second round of chest compressions on the CPR
148 canine manikin^b in lateral recumbency at the same table height as Cycle 1, with the assigned
149 auditory aid playing. Again, a camera was used to record all sessions and no study investigator
150 counted the number of compressions during the cycle. The same study investigator again started
151 the video recording and then timed the 2-minute cycle with a stopwatch, communicating the start
152 and end time of the cycle to the study participant.

153

154 **Compression rate assessment**

155 Following recruitment of all participants, both study investigators independently assessed
156 the video recordings of each participant to count the number of compressions administered during
157 Cycle 1 and Cycle 2. For each cycle, the number of compressions administered during the 1st and 2nd
158 minute was recorded. Each video was evaluated twice by both study investigators and then the
159 results were reviewed. If there was a disagreement (defined as anything but the same exact same
160 number), the senior investigator reviewed the videos on a third occasion and the values obtained
161 during that review were used. Investigators were not blinded to the study group the participant was
162 assigned to.

163 **Statistical Analyses**

164 Continuous data was assessed for normality using a Shapiro-Wilk test and all data was non-
165 normally distributed. Quantitative parameters were expressed as medians and range (minimum –
166 maximum). Chi squared test was used to assess categorical data from independent groups. Kruskal-
167 Wallis testing was used to assess the median compression rates between groups. Post hoc testing
168 with Dunn’s multiple comparison test was performed to identify significant variables **between**
169 **individual groups**. A Wilcoxon matched pairs signed rank test was used to compare compression
170 rates between the 1st and 2nd minute of cycle 1 and cycle 2 and to compare compression rate
171 without and with an auditory aid for each participant. McNemar’s test was used to assess the
172 successful compression rate of individuals without and with an auditory aid. All statistical analyses
173 were performed using a commercially available program.^c Significance was set at p value < 0.05.

174

175 To achieve a power of 80% and a level of significance of 5% (two sided) for detecting an
176 effect size of 0.8 between pairs (without and with an auditory aid), a sample size of **16 participants**
177 was determined to be needed.

178

179 Results

180 A total of 36 participants (20 veterinarians and 16 RVNs) were successfully enrolled within
181 the study. Twelve participants were enrolled into each auditory aid group. Participant demographics
182 for each study group can be found in Table 1. There were no significant differences among the
183 groups. When comparing participant demographics based on profession (i.e., veterinarian versus
184 RVN), a significantly higher number of RVNs worked primarily within ECC compared to veterinarians
185 ($p=0.006$) but no other significant differences were identified (number of years qualified, $p=0.7016$;
186 frequency CPR performed, $p=0.5136$; date of last CPR training, $p>0.9999$; completion of any
187 RECOVER training, $p=0.1914$).

188

189

190 *Cycle 1: Without an auditory aid*

191 The median (range) number of compressions administered by participants during the 1st and
192 2nd minute of chest compressions was 111 (range 88-140) and 107 (range 80-151), respectively
193 (Figure 1). There was no significant difference of the number of compressions administered by each
194 participant during minute 1 and minute 2 ($p=0.2519$).

195

196 A total of 25/36 (69%) participants successfully performed compressions at a rate within the
197 recommended 100-120 cpm range for both minute 1 and minute 2 of Cycle 1 (Figure 2). Of the 11
198 individuals who were outside this range, 9 (82%) did not perform compressions in the range of 100-
199 120 during the entire cycle while 1 (9%) performed compressions faster in minute 1 and 1 (9%)
200 slower in minute 2. A significantly higher number of veterinarians compared to RVNs administered
201 compressions outside the 100-120 cpm target ($p=0.0091$) (Table 2). No other significant
202 demographic differences were found between participants delivering appropriate compared to
203 inappropriate compression rates (Table 2). There was no significant difference among the three
204 study groups in number of individuals administering appropriate compression rates compared to
205 inappropriate compressions ($p=0.072$).

206

207 The median compression rates administered within each group for minute 1 and minute 2
208 can be found in Figure 3. There was no difference in median compression rate prior to study group
209 randomization ($p=0.8665$). There was also no difference in median compression rate between the 1st
210 and 2nd minute for individuals within each group (Group B, $p = 0.5186$; Group Q, $p = 0.3125$; Group
211 M, $p = 0.0586$).

212

213 A mental metronome was self-reported to have been used by 28/36 (78%) participants
214 during Cycle 1 of chest compressions. The mental metronomes used were Bee Gees' "Stayin' Alive"
215 ($n=20$), Queen "Another One Bites the Dust" ($n=4$), Nellie the Elephant ($n=1$) and 3 participants did
216 not state what mental metronome they used. Participants utilizing a mental metronome were not
217 more likely to be successful at administering compressions within the rate of 100-120 per minute
218 than those who did not ($p = 0.3884$).

219

220 ***Cycle 2: With an auditory aid***

221 The median number of compressions administered during the 1st and 2nd minute for all
222 individuals was 110 (range 76-125) and 110 (range 72-125), respectively (Figure 1). Participants had
223 a higher compression rate during minute 1 compared to minute 2 of the cycle ($p = 0.0164$). A total of
224 34/36 (94%) participants successfully administered a compression rate within the recommended
225 100-120 cpm for both minute 1 and minute 2 of the cycle (Figure 2). All individuals in Group Q and M
226 had appropriate compression rates during the entire cycle of CPR while 2 individuals in group B had
227 inappropriate compression rates during the entire cycle, however, this did not reach statistical
228 significance ($p=0.1203$).

229

230 The median compression rates administered by the participants among each group for
231 minute 1 and minute 2 can be found in Figure 3. When assessing individuals among the 3 study

232 groups, a significant difference in the number of compressions administered during the cycle was
233 identified ($p = 0.0001$) (Figure 3). Post hoc analysis identified that Group B participants administered
234 a significantly lower number of compressions compared to participants in Group Q and Group M. No
235 differences between Group M and Group Q were found. There was no difference in median
236 compression rate between the 1st and 2nd minute for individuals within each group (Group B, $p =$
237 0.0781 ; Group Q, $p = 0.584$; Group M, $p = 0.1328$) (Figure 3).

238
239

240 ***Comparing compressions without and with auditory aid***

241 The number of compressions administered by each participant during Cycle 1 and Cycle 2
242 were not significantly different ($p=0.3996$ and 0.4629 , respectively). However, subgroup analysis
243 identified that participants in Group B had a significantly higher cpm rate during both minute 1 and
244 minute 2 of Cycle 1 compared to minute 1 and minute 2 of Cycle 2 ($p = 0.022$ and 0.0273 ,
245 respectively). No significant differences in cpm rates were found between minute 1 and minute 2 of
246 Cycle 1 and Cycle 2 for participants in Group Q and Group M ($p=0.9453$, 0.8945 , 0.6382 , 0.6587 ,
247 respectively).

248

249 Participants were significantly more likely to administer chest compressions within the
250 recommended range of 100-120 cpm when an auditory aid was present compared to without an
251 auditory aid ($p=0.013$). When specifically evaluating groups, participants in group Q ($p = 0.014$) and
252 group M ($p = 0.0455$) were significantly more likely to achieve a compression rate within 100-
253 120cpm when an auditory aid was present, but the auditory aid did not improve compression rate
254 accuracy for Group B participants ($p = 0.5637$).

255

256
257

258 Discussion

259 The findings of this study suggest that the use of an auditory aid during chest compressions
260 may help improve chest compression **rate** accuracy when performed on a canine manikin.⁸ Without
261 the presence of an auditory aid, 69% of participants successfully administered chest compressions
262 within the recommended range of 100-120 cpm, with this number increasing to 94% when an
263 auditory aid was present.

264

265 Several studies have evaluated chest compression rate accuracy delivered by human medical
266 personnel during CPR in relation to CPR guidelines in both simulator and clinical settings, with
267 accuracy rates ranging from 15% - 80.3% having been documented.^{9,13,14,25,26} To the authors
268 knowledge, there are only two studies evaluating chest compression rate accuracy in accordance
269 with RECOVER guidelines in dogs and cats.^{10,11} The chest compression accuracy rate of 69% within
270 our study is encouraging and similar to the 76% reported in a prospective, clinical study.¹¹ However,
271 direct comparison of results is difficult acknowledging that this previous study was not specifically
272 focused on assessing chest compression rate accuracy with compression rates not being objectively
273 measured. Additionally, as only one compression rate was recorded for each CPR event, there was
274 no consideration for potential variability in compression rate during each CPR cycle and amongst
275 team members. Our accuracy rate is higher than the 53% accuracy rate reported by Kneba et al for a
276 group of veterinary students **enrolled in a manikin study**, which can likely be explained by most of
277 our participants having at least some prior CPR experience.¹⁰

278

279 Profession of the participant was the only significant difference in participant demographics
280 when comparing those who were successful compared to unsuccessful at administering a chest
281 compression rate in the range of 100-120 cpm during Cycle 1. **RVNs were more likely to achieve a**
282 **compression rate within this range compared to veterinarians more likely to be outside the range.**

283 This finding may be related to there being a significantly greater number of RVN participants
284 primarily working in ECC compared to veterinarians. However, with no differences between the
285 veterinarian and RVN participants in relation to frequency CPR performed, date of last CPR training
286 or completion of RECOVER training to offer further explanation, this finding may purely be
287 coincidental and related to the small participant number of the study.

288

289 Most of our participants (78%) stated that they used a mental metronome during Cycle 1 to help
290 set a tempo. However, there was no difference in compression rate accuracy for those who used a
291 mental metronome compared to those who did not. Kneba et al. identified that the accuracy of
292 chest compression rate decreased approximately 10 weeks following initial training with an auditory
293 aid, with 72% participants successfully delivering compressions at a rate of 100-120 cpm compared
294 to 50% participants who had not received any training with an auditory aid.¹⁰ The absence of a
295 beneficial effect of use of a mental metronome within this study may be the result of a
296 heterogenous population in relation to date of last training, potential differences in CPR training or
297 due to the majority of participants using 'Stayin' Alive' as a mental metronome which the results
298 reported here suggest may be an inferior auditory aid.

299

300 A number of popular songs have been reported to help aid chest compression rate accuracy by
301 acting as an auditory aid, with perhaps the most well-known being the Bee Gee's aptly named
302 'Stayin' Alive'. A 2021 systemic review concluded that the use of songs as auditory aids should be
303 considered when teaching CPR, however, it was not able to make any formal recommendations
304 relating to the optimum song/s nor the optimum song beats per minute.²⁷ We chose to use 'Stayin'
305 Alive' and Queen's 'Another One Bites the Dust' as auditory aids in this study as both songs have a
306 rate within the 100-120 beats per minute range and are well known songs commonly used as part of
307 CPR training within our hospital. Matlock et al. first suggested use of Bee Gee's 'Stayin' Alive' as an
308 aid to help pace chest compressions following the finding that 15 healthcare professionals

309 administered a mean compression rate of 109.1 cpm during training when this song was playing and
310 felt utilizing music helped them improve their ability to provide CPR in accordance with the then
311 current guidelines.²⁴ Since then, 'Stayin' Alive has been found to be beneficial when used as a mental
312 metronome, aiding both short and long term recall of optimal chest compression rate, however,
313 there is a scarcity of evidence evaluating its role on chest compression rate accuracy when
314 playing.^{10,15,22} The positive lyrics of 'Stayin' Alive' are in stark contrast to those of Queen's 'Another
315 One Bites the Dust' and likely the reason why the authors are not aware of any prior studies which
316 have assessed the utility of this song as a CPR aid in either a training or clinical setting. The use of a
317 traditional metronome as an auditory aid is reported to have a beneficial effect on compression rate
318 accuracy when used by both medical personnel and bystanders, however, this may be a less
319 effective memory aid.^{8,9,14,16,18,21}

320

321 Group B participants had significantly lower compression rates compared to those in Group Q
322 and Group M during Cycle 2. This can be explained by the lower beats per minute rate of the song
323 'Stayin' Alive' (103 bpm) compared to 'Another One Bites the Dust' and the metronome both being
324 at 110 beats per minute. Assessing number of participants who achieved a compression rate
325 between 100-120 per minute with an auditory aid is likely a more clinically useful way to assess the
326 usefulness of auditory aids during chest compressions compared to the compression rate itself.
327 When an auditory aid was present, compression rate accuracy was 94% for all participants,
328 indicating that an auditory aid was helpful to pace compressions in this study. Subgroup analysis
329 suggested an improved compression rate accuracy for participants in Group Q and Group M when an
330 auditory aid was present, but no beneficial effect was found for Group B. Further evaluation of these
331 findings identified the two participants who were not successful at achieving a compression rate of
332 100-120 cpm with an auditory aid were both in Group B and likely explains why the Group B auditory
333 aid was not beneficial. The authors hypothesize that the beat of the song 'Stayin' Alive' may not be
334 as discernable compared to the other auditory aids to offer an explanation for this finding. However,

335 despite two individuals not achieving the optimal compression rate in Group B, the clinical relevance
336 should be considered. The recommended 100-120 cpm is based on the results of an experimental
337 study which identified a higher rate of ROSC with compressions at 120 per minute compared to 60
338 per minute.⁷ Therefore, the individual who administered chest compression rates below 100 cpm in
339 this study may have administered chest compressions so low that it would be clinically relevant and
340 potentially detrimental. In contrast, one participant achieved a compression rate just above the
341 recommend range and the clinical impact of this is unknown at present. These findings provide
342 preliminary evidence that some auditory aids are more beneficial than others. Our results suggest
343 that an auditory aid with a beat that lies well within the RECOVER recommended 100-120 cpm may
344 be more beneficial than one that barely lies within this range.

345

346 The 2012 RECOVER guidelines do not provide any guidance on the use of auditory aids during
347 CPR, and current human guidelines suggest that an auditory aid may be useful but are not able to
348 make recommendations on the most appropriate form or tempo.^{2,23,28} Our study results indicate that
349 compression rate accuracy may be influenced by the auditory aid used and suggest that a traditional
350 metronome or 'Another One Bites the Dust' may be used as an auditory aid following
351 documentation of improved compression rate accuracy with these auditory aids. Perhaps in a clinical
352 setting, the authors speculate that the use of a traditional metronome would be most appealing. In
353 addition to many defibrillator units now having an inbuilt metronome, a traditional metronome
354 would eliminate the potential need for familiarization of songs and ability to discern the beat from
355 within the song. There is also the potential concern for loss of professionalism associated with use of
356 a music aid, especially in a clinical setting, which would be eliminated if a traditional metronome
357 were used.

358

359 Despite no studies evaluating optimal timing of CPR cycles in dogs and cats, the 2012 RECOVER
360 guidelines advise that chest compressions should be performed in 2- minute cycles without

361 interruption based on several high-quality prospective and retrospective human studies.^{29,30} These
362 studies concluded that uninterrupted cycles of basic life support of 2 minutes resulted in better
363 survival and neurological outcomes than shorter cycle, however, some other studies suggest that
364 rescuer fatigue may decrease quality of chest compressions after only 1 minute.³¹ To the authors
365 knowledge, this is the first study to attempt to assess cpm during the first and second minute of a 2-
366 minute CPR cycle, with and without an auditory aid, in veterinary medicine. We did not demonstrate
367 compressor fatigue between minute 1 and minute 2 of Cycle 1, with no difference in cpm being
368 found when an auditory aid was not present (Cycle 1). When assessing the whole study population
369 with an auditory aid, participants were found to have a significantly higher cpm rate during the 1st
370 minute compared to the 2nd minute of Cycle 2, but this significant difference was lost when assessing
371 participants in each study group. The exact significance of this is unknown and is unlikely of clinical
372 relevance but further studies are required to evaluate further. Comparing number of cpm of Cycle 1
373 to that of Cycle 2 was not significantly different for all participants, suggesting that there was no
374 evidence of compressor fatigue and that participants had ample time for recovery between cycles.
375 However, participants in Group B were found to have a significantly lower cpm rate during Cycle 2
376 compared to Cycle 1. This can be explained by the finding that the BPM of 'Stayin' Alive' is lower
377 than the median cpm documented in Cycle 1 at 110.5 cpm for minute 1 and 105.5 cpm for minute 2.
378 No significant differences in cpm by each participant during minute 1 or minute 2 of Cycle 1 or Cycle
379 2 for participants in group Q or M were found.

380

381 This study has several limitations. Chest compressions were carried out on a manikin,^b in an
382 artificial environment, without the noise and stress typically associated with resuscitation efforts,
383 and so it is unknown how transferable these results are to a clinical setting. The implementation of
384 an auditory aid during CPR must be in addition to a primary focus on providing high quality basic life
385 support, which includes chest compression depth, adequate chest recoil and chest compression
386 point. The stiff nature of the canine CPR mannequin used within this study precluded our ability to

387 assess compression depth accuracy. Some human studies have suggested that although an auditory
388 aid may improve compression rate accuracy, compression rate depth decreased.^{13,15-17,21} Further
389 studies are required to assess the impact of the use of an auditory aid on compression depth in
390 veterinary patients.

391

392 Additional limitations include this study being carried out in one referral hospital and so it is
393 unknown if our results are representative of other settings. This study recruited participants on a
394 volunteer basis and so may have inadvertently selected for certain personality types (e.g., more
395 confident individuals). The small sample size should be considered when interpreting the significant
396 finding that the auditory aid in Group B did not improve chest compression accuracy rate, especially
397 as this finding appeared to be driven by data from only 2 participants. Participants were also always
398 asked to complete chest compressions without an auditory aid first, potentially leading to either a
399 learned effect or increasing likelihood of fatigue for Cycle 2. This was however intentional as we
400 wanted to assess compression rate accuracy of the clinical staff members without an auditory aid to
401 begin with and tried to mitigate the effect of fatigue by providing participants with recovery time
402 akin to what would be similar in real life CPR efforts. Finally, the practice periods of 10 minutes prior
403 to recording Cycle 2 of chest compressions could furthermore have led to a learned effect of how to
404 best optimize use of the auditory aid.

405

406 In conclusion, an auditory aid was found to be of value at increasing the likelihood of
407 participants administering compressions within the targeted range amongst a population of
408 veterinarians and RVNs. This study provides preliminary evidence that auditory aids with higher
409 underlying beats (110bpm) may be more beneficial to help rescuers reach the target compression
410 rates of 100-120 per minute than auditory aids with a beat at the lower end of this spectrum (103
411 for 'Stayin' Alive'). Our results suggest that a music aid or traditional metronome may be considered,
412 but the authors speculate that a traditional metronome may be preferred to maintain

413 professionalism in a clinical setting and eliminate need for song familiarization, but further studies

414 must be conducted to determine the most valuable auditory aid.

415

416 **Table 1: Participants were assigned to one of three study groups where they performed chest**
 417 **compressions on a canine CPR manikin with the song 'Stayin' Alive' (Group B), 'Another One Bites**
 418 **the Dust' (Group Q) or a traditional metronome (Group M) as an auditory aid. Participant**
 419 **demographics are shown along with results of statistical analyses of study group comparisons (Chi-**
 420 **squared test) . A p value < 0.05 was considered statistically significant.**

421

	Group B (N)	Group Q (N)	Group M (N)	P value
Participants:				
Vets	6	6	8	>0.99
RVNs	6	6	4	
Number of individuals primarily working within ECC	3/12	5/12	7/12	0.2636
Year qualified as veterinarian or RVN				0.2740
< 2 years ago	0	3	2	
2-5 years ago	3	3	4	
6-10 years ago	6	3	5	
11-15 years ago	2	1	0	
16 years +	1	2	1	
Frequency CPR performed				0.4931
At least once per week	0	1	1	
At least once per month	4	3	6	
At least once every 6 months	6	5	3	
At least once per year	0	1	1	
Less than once per year	1	1	0	
Never	1	1	1	
Date of last CPR training session				0.4971
Within past 3 months	1	3	2	
Within past 6 months	3	0	2	
Within past 12 months	4	4	6	
More than a year ago	4	4	1	
Never received any training	0	1	1	
Completed any RECOVER training				0.9605
Yes	5	9	8	
None	8	5	4	

422

423 *Abbreviations: BLS, basic life support; CPR, cardiopulmonary resuscitation; N, number of participants;*424 *RECOVER, Reassessment Campaign on Veterinary Resuscitation; RVN, registered veterinary nurse*

425 **Table 2: During Cycle 1, participants performed 2 minutes' worth of chest compressions on a CPR**
 426 **canine manikin without an auditory aid. They were instructed to obtain a rate of 100-120**
 427 **compressions per minute. Participant demographics are shown for those who were successful and**
 428 **unsuccessful at achieving this rate are shown along with results of statistical analyses comparing**
 429 **these two groups (Chi-squared test). A p value < 0.05 was considered statistically significant.**

430

	Compression rate in range 100-120 cpm during Cycle 1 (N)	Compression rate outside 100-120 cpm during Cycle 1 (N)	P value
Participants:			
Vets	10	10	0.0091
RVNs	15	1	
Number of individuals primarily working within ECC	13/25	2/11	0.0769
Year qualified as veterinarian or RVN			0.4361
< 2 years ago	2	3	
2-5 years ago	8	2	
6-10 years ago	9	4	
11-15 years ago	3	1	
16 years +	3	1	
Frequency CPR performed			0.4972
At least once per week	2	0	
At least once per month	7	6	
At least once every 6 months	11	3	
At least once per year	1	1	
Less than once per year	1	1	
Never	3	0	
Date of last CPR training session			0.8838
Within past 3 months	4	2	
Within past 6 months	5	0	
Within past 12 months	8	6	
More than a year ago	6	3	
Never received any training	2	0	
Completed any RECOVER training			

Yes	14	6	0.9355
No	11	5	

431

432 *Abbreviations: cpm, compressions per minute; CPR, cardiopulmonary resuscitation; N, number of*433 *participants; RECOVER, Reassessment Campaign on Veterinary Resuscitation; RVN, registered*434 *veterinary nurse*

435

436 **Footnotes**437 ^a MetroTimer app, Version 3.3.5, for Apple iPhone

438

439 ^b Jerry K-9 CPR manikin, Rescue Critters, Simi Valley, CA

440

441 ^c GraphPad Prism, Version 9.3.1(350) for Mac OS X, GraphPad Software, San Diego, CA.

442

443 **References**

444

445 1. Panchal AR, Bartos JA, Cabañas JG, et al. Adult Basic and Advanced Life Support Writing
446 Group. Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association
447 Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care.
448 *Circulation*. 2020;142(16_suppl_2):S366-S468.

449

450 2. Olasveengen TM, Semeraro F, Ristagno G, et al. European Resuscitation Council Guidelines
451 2021: Basic Life Support. *Resuscitation*. 2021;161:98-114.

452

453 3. Hopper K, Epstein SE, Fletcher DJ et al. RECOVER evidence and knowledge gap analysis on
454 veterinary CPR. Part 3: Basic life support. *J Vet Emerg Crit Care*. 2012;22 (S1):S26-S43.

455

456 4. Deasy C, Bray JE, Smith K, et al. Cardiac arrest outcomes before and after the 2005
457 resuscitation guidelines implementation: evidence of improvement? *Resuscitation*.
458 2011;82(8):984–988.

459

460 5. Hinchey PR, Myers JB, Lewis R, et al. Improved out-of-hospital cardiac arrest survival after
461 the sequential implementation of 2005 AHA guidelines for compressions, ventilations, and
462 induced hypothermia: the Wake County experience. *Ann Emerg Med*. 2010;56(4):348–357.

463

464 6. Aufderheide TP, Yannopoulos D, Lick CJ, et al. Implementing the 2005 American Heart
465 Association Guidelines improves outcomes after out-of-hospital cardiac arrest. *Heart
466 Rhythm*. 2010;7(10):1357–1362.

467

- 468 7. Feneley MP, Maier GW, Kern KB. Influence of compression rate on initial success of
469 resuscitation and 24-hour survival after prolonged manual cardiopulmonary resuscitation in
470 dogs. *Circulation*. 1988;77(1):240-50.
- 471 8. Hong C, Hwang S, Lee K, et al. Metronome vs. Popular Song: A Comparison of Long-Term
472 Retention of Chest Compression Skills after Layperson Training for Cardiopulmonary
473 Resuscitation. *Hong Kong Journal of Emergency Medicine*. 2016;23(3):145-152.
- 474
475
- 476 9. Khorasani-Zadeh A, Krowl LE, Chowdhry AK, et al. Usefulness of a metronome to improve
477 quality of chest compressions during cardiopulmonary resuscitation. *Proc (Bayl Univ Med*
478 *Cent)*. 2020;34(1) 54–55.
- 479
- 480 10. Kneba EJ, Humm KR. The use of mental metronomes during simulated cardiopulmonary
481 resuscitation training. *J Vet Emerg Crit Care*. 2020;30:92-96.
- 482
- 483 11. Hoehne SN, Hopper K, Epstein SE. Prospective Evaluation of Cardiopulmonary Resuscitation
484 Performed in Dogs and Cats According to the RECOVER Guidelines. Part 2: Patient Outcomes
485 and CPR Practice Since Guideline Implementation. *Front Vet Sci*. 2019;6:439.
- 486
- 487 12. Rawlins L, Woollard M, Williams J, et al. Effect of listening to Nellie the Elephant during CPR
488 training on performance of chest compressions by lay people: randomised crossover trial. *Br*
489 *Med J*. 2009;339:b4707
- 490
- 491 13. Woollard M, Poposki J, McWhinnie B, et al. Achy breaky makey wakey heart? A randomised
492 crossover trial of musical prompts. *Emerg Med J*. 2012;29:290-294.
- 493

- 494 14. Kern KB, Stickney RE, Gallison L, Smith RE. Metronome improves compression and
495 ventilation rates during CPR on a manikin in a randomized trial. *Resuscitation*.
496 2010;81(2):206-10.
497
- 498 15. Hafner JW, Jou AC, Wang H, et al. Death before disco: the effectiveness of a musical
499 metronome in layperson cardiopulmonary resuscitation training. *J Emerg Med*.
500 2015;48(1):43-52.
501
- 502 16. Zimmerman E, Cohen N, Maniaci V, et al. Use of a Metronome in Cardiopulmonary
503 Resuscitation: A Simulation Study. *Pediatrics*. 2015;136(5):905-11.
504
- 505 17. Park SO, Hong CK, Shin DH, et al. Efficacy of metronome sound guidance via a phone speaker
506 during dispatcher-assisted compression-only cardiopulmonary resuscitation by an untrained
507 layperson: a randomised controlled simulation study using a manikin. *Emerg Med J*.
508 2013;30(8):657-61.
509
- 510 18. Yang D, Lee W, Oh J. Effect of the Use of Metronome Feedback on the Quality of Pediatric
511 Cardiopulmonary Resuscitation. *Int J Environ Res Public Health*. 2021;18(15):8087.
512
- 513 19. Roehr CC, Schmörlzer GM, Thio M, et al. How ABBA may help improve neonatal resuscitation
514 training: auditory prompts to enable coordination of manual inflations and chest
515 compressions. *J Paediatr Child Health*. 2014;50(6):444-8.
516
- 517 20. Çalışkan D, Bildik F, Aslaner M, et al. Effects of metronome use on cardiopulmonary
518 resuscitation quality. *Turk J Emerg Med*. 2021;21(2) 51–55.
519

- 520 21. Jäntti H, Silfvast T, Turpeinen A, et al. Influence of chest compression rate guidance on the
521 quality of cardiopulmonary resuscitation performed on manikins. *Resuscitation*.
522 2009;80(4):453-7.
- 523 22. Tastan S, Ayhan H, Unver V, et al. The effects of music on the cardiac resuscitation education
524 of nursing students. *Int Emerg Nurs*. 2017;31:30-35.
- 526
- 527 23. Cheng A, Magid DJ, Auerbach M, et al. Part 6: Resuscitation Education Science: 2020
528 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency
529 Cardiovascular Care. *Circulation*. 2020;142(16_suppl_2):S551-S579.
- 530 24. Matlock D, Hafner JWJ, Bockewitz EG, et al. 83: "Stayin' Alive": A Pilot Study to Test the
531 Effectiveness of a Novel Mental Metronome in Maintaining Appropriate Compression Rates
532 in Simulated Cardiac Arrest Scenarios. *Ann Emerg Med*. 2008;52(4):S67-S68.
- 534
- 535 25. Loza-Gomez A, Johnson M, Newby M, et al. Chest Compression Fraction Alone Does Not
536 Adequately Measure Cardiopulmonary Resuscitation Quality in Out-of-Hospital Cardiac
537 Arrest. *J Emerg Med*. 2022;62(3):e35-e43.
- 538
- 539 26. Cuvelier Z, Houthoofd R, Serraes B, et al. Effect of a backboard on chest compression quality
540 during in-hospital adult cardiopulmonary resuscitation: A randomised, single-blind,
541 controlled trial using a manikin model. *Intensive Crit Care Nurs*. 2022;69:103164.
- 542
- 543 27. Pellegrino JL, Vance J, Asselin N. The Value of Songs for Teaching and Learning
544 Cardiopulmonary Resuscitation (CPR) Competencies: A Systematic Review. *Cureus*. 2021;
545 16;13(5):e15053.
- 546

547

548

549 28. Fletcher DJ, Boller M, Brainard BM, et al. American College of Veterinary Medicine;
550 Veterinary Emergency and Critical Care Society. RECOVER evidence and knowledge gap
551 analysis on veterinary CPR. Part 7: Clinical guidelines. J Vet Emerg Crit Care. 2012;22 Suppl 1:
552 S102-31.

553

554 29. Mosier J, Itty A, Sanders A, et al. Cardiocerebral resuscitation is associated with improved
555 survival and neurologic outcome from out-of-hospital cardiac arrest in elders. Acad Emerg
556 Med. 2010;17(3):269-75.

557

558 30. Kellum MJ, Kennedy KW, Barney R, et al. Cardiocerebral resuscitation improves
559 neurologically intact survival of patients with out-of-hospital cardiac arrest. Ann Emerg Med.
560 2008;52(3):244-52.

561

562 31. Ochoa FJ, Ramalle-Gomara E, Lisa V, et al. The effect of rescuer fatigue on the quality of
563 chest compressions. Resuscitation. 1998;37:149-52.

564

565 **Figure 1:** Box and whisker plots representing the median number of compressions per minute and
566 interquartile range administered by the participants without an auditory aid (Cycle 1) and with
567 auditory aid (Cycle 2). The whiskers represent the minimum and maximum number of compressions
568 administered. The dashed lines indicate the upper (120 cpm) and lower (100 cpm) limits of the
569 desired range.

570

571 **Figure 2:** Success rates of individuals achieving 100-120 compressions per minute (cpm) without an
572 auditory aid (Cycle 1) and with an auditory aid (Cycle 2).

573

574 **Figure 3:** Box and whisker plots representing the median number of compressions per minute and
575 interquartile range administered by the participants in each group without an auditory aid (Cycle 1)
576 and with auditory aid (Cycle 2). A different auditory aid was used during Cycle 2 for participants
577 assigned to each group: 'Stayin' Alive' (Group B), 'Another One Bites the Dust' (Group Q) and
578 traditional metronome (Group M). The whiskers represent the minimum and maximum number of
579 compressions administered. The dashed lines indicate the upper (120 cpm) and lower (100 cpm)
580 limits of the desired range. Individual data points are also shown.

581