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## Normative values for gastric motility assessed with the 3D-transit electromagnetic tracking system

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*Published in:*  
Neurogastroenterology and Motility

*DOI (link to publication from Publisher):*  
[10.1111/nmo.13829](https://doi.org/10.1111/nmo.13829)

*Publication date:*  
2020

*Document Version*  
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Sutter, N., Klinge, M. W., Mark, E. B., Nandhra, G., Haase, A-M., Poulsen, J., Knudsen, K., Borghammer, P., Schlageter, V., Birch, M., Scott, S. M., Drewes, A. M., & Krogh, K. (2020). Normative values for gastric motility assessed with the 3D-transit electromagnetic tracking system. *Neurogastroenterology and Motility*, 32(6), Article e13829. Advance online publication. <https://doi.org/10.1111/nmo.13829>

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1 **MAIN TITLE**

2 Normative values for gastric motility assessed with the 3D-transit electromagnetic tracking  
3 system

4 **RUNNING TITLE**

5 Normative values for gastric motility patterns

6

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30 **Abstract**

31 **Background**

32 The Motilis 3D-Transit system allows ambulatory description of transit patterns throughout  
33 the gastrointestinal tract and offers an alternative method for studying gastric motility. We  
34 aimed to establish normative values for gastric motility assessed with the method.

35 **Method**

36 A total of 132 healthy volunteers ingested the 3D-Transit capsule for assessment of  
37 gastrointestinal transit times. Recordings from 125 subjects were used for definition of  
38 normative values. 46 subjects were studied on two consecutive days. Recordings were  
39 reanalysed using newly developed software providing information on gastric emptying (GE) as  
40 well as contraction frequency and movement during gastric contractions.

41 **Results**

42 The median GE time was 2.7 hours (range 0.1-21.2). In 89% of subjects, the capsule passed  
43 the pylorus within a post-ingestion period of 6 hours. The median frequency of gastric  
44 contractions was 3.1 per minute (range 2.6-3.8). The frequency was higher in women (3.2,  
45 range 2.7-3.8) than in men (3.0, range 2.6-3.5) and increased with age (0.004 per year)  
46 ( $p < 0.05$ ). The median amplitudes were  $35^\circ$  (range 4-85) when based on rotation of the capsule  
47 and 11 mm (range 6-31) when based on capsule change in position. The rotation amplitude  
48 was higher in women and decreased with increasing BMI ( $p < 0.05$ ). The position amplitude was  
49 also higher in women and increased with the amount of calories in the test meal, but  
50 decreased with increasing BMI and age ( $p < 0.05$ ). Day-to-day variation ( $p > 0.05$ ) was  
51 considerable while inter-rater variability was small.

52 **Conclusion & inferences**

53 We have established normative values for gastric motility assessed with the 3D-Transit  
54 system.

55

56 **KEYWORDS**

57 Gastroenterology, Neurogastroenterology, Gastrointestinal motility, Gastric Motility

58

59 **ABBREVIATIONS**

60 GE: Gastric emptying; BMI: Body Mass Index,

## 61 Introduction

62 Gastroparesis is defined as delayed gastric emptying with absence of mechanical obstruction.  
63 The most common aetiologies are diabetes mellitus, surgery, neurological disorders and viral  
64 infections<sup>1, 2</sup>. However, in a significant proportion of patients, gastroparesis remains  
65 idiopathic<sup>1, 2</sup>. Symptoms are usually non-specific, such as nausea, vomiting, bloating, upper  
66 abdominal discomfort, pain, postprandial fullness and early satiety<sup>3</sup>. **Even though symptoms**  
67 **vary, nausea and vomiting are predominant symptoms in diabetic gastroparesis whereas**  
68 **abdominal pain is more common in idiopathic gastroparesis<sup>1, 4</sup>. Likewise the severity of**  
69 **symptoms varies<sup>5</sup> with severe cases having reduced quality of life and frequent hospitalisation**  
70 **due to the cardinal symptoms or dehydration and poor glycaemic control<sup>1, 3, 4, 6, 7</sup>. In the United**  
71 **States of America, prevalence is estimated at 19.6 per 100.000 men and 37.8 per 100.000**  
72 **women<sup>8</sup>, though gastroparesis likely remains unrecognised in many subjects<sup>8, 9</sup>.**

73           Gastric emptying assessed by scintigraphy is currently the gold standard for  
74 diagnosis of gastroparesis. The method quantifies the emptying of a solid-phase, egg-based,  
75 radiolabelled meal that is imaged after 30 minutes and thereafter every hour for at least 4  
76 hours<sup>10</sup>. The validity of scintigraphy requires that internationally accepted protocols are  
77 strictly followed<sup>11</sup>. Nevertheless, **the clinical use of results from scintigraphy is widely debated**  
78 **and results do not predict response to treatment<sup>12, 13</sup>**. This limitation could be because  
79 scintigraphy only describes gastric emptying while other parameters of gastric motility (e.g  
80 parameters of contractile activity) could be equally important. Furthermore, scintigraphy is  
81 expensive, requires the intake of radioactive isotopes and only determines passage from the  
82 stomach. The latter is a major limitation as many motility disorders are pan-enteric and not  
83 restricted to a single region of the gastrointestinal tract<sup>14</sup>.

84                   Gastric emptying can also be determined by breath test measuring the stable  
85 isotope  $^{13}\text{C}$ .<sup>15</sup> This test can be performed in an ambulatory setting without use of extensive  
86 equipment and the exposure to irradiation<sup>16, 17</sup>. The wireless motility capsule (Smartpill™  
87 Medtronic Corporation, Buffalo, NY, USA) is a US Food and Drug Administration and  
88 European Union-approved capsule system for ambulatory investigation of total and regional  
89 gastrointestinal transit times. The system measures pH, pressure and temperature  
90 throughout the gastrointestinal tract. However, the interpretation of pressure data is  
91 complicated as the capsule advances in the gut on the same pressure events that it seeks to  
92 record and the exact location of the capsule on a minute-to-minute basis is unknown<sup>18-20</sup>.

93                   The 3D-Transit system (Motilis Medica SA, Lausanne, Switzerland) is an  
94 ambulatory minimally invasive, radiation-free capsule system that allows detailed  
95 investigation of the entire gastrointestinal tract as it tracks the precise position and  
96 orientation of an electromagnetic capsule. Examinations can be performed at home under  
97 near-normal conditions and provide information on gastric emptying time, small intestinal  
98 transit time, total and segmental colonic transit time, and movement patterns within the  
99 colon<sup>21</sup>.

100                   Recent development of software for analysis of recordings obtained by 3D-  
101 Transit now enables assessment of the frequency and amplitude of either rotation or change  
102 in position of the capsule within the stomach. As the 3D-Transit is a relatively novel research  
103 tool, it is important to define normal ranges of motility parameters described by the method.  
104 Therefore, the aim of the present study was to establish normative data for gastric emptying  
105 and gastric contractile activity assessed with the 3D-Transit system. Furthermore, we aimed  
106 to determine if gastric emptying and gastric contractions were affected by age, gender, body  
107 mass index (BMI), or the content of the test meal taken with the 3D-Transit capsule.

## 108 **Material and Methods**

### 109 **Study population**

110 For the present study, we reanalysed 3D-Transit data from 132 volunteers who had served as  
111 healthy controls in previous studies at Aarhus and Aalborg University Hospitals, Denmark, and  
112 Queen Mary University London, UK. Among the 132 subjects, 46 had ingested capsules on two  
113 consecutive days. All studies were carried out in accordance with the declaration of Helsinki  
114 and after approval by local Research Ethical Committees (reference numbers: 1-10-72-54-15,  
115 2016101143; N-2013-0030, 2013070299; M-2010-0276, 2011-123594; 1-10-72-356-12, 2012-  
116 003939-27; 1-10-72-255-14, 2014-112300; M-2014-213-14, 2014-080548, 2015-033891; 1-  
117 10-72-211-15, 2015-093124 and 15/LO/1039)(see appendix A). Data for GE times in some of  
118 the subjects have been published previously<sup>21-26</sup>. Informed consent was obtained from all  
119 participants before enrolment.

120 All subjects were without previous history of serious gastrointestinal disease or  
121 other conditions affecting bowel function and none took medication affecting gastrointestinal  
122 motility.

123

### 124 **The 3D-Transit system**

125 The 3D-Transit system consists of an electromagnetic capsule (21.5 millimetres x 8.3  
126 millimetres, 1.6 gram per cm<sup>3</sup>), an extracorporeal detector containing four sensors to register  
127 the electromagnetic field emitted by the capsule, and software for display and analysis of data.  
128 The battery lifetime of the capsule is approximately 60 hours at 10 Hertz sampling rate.  
129 However, the sampling rate is adjustable and in most of the studies above it was set at 5 Hertz  
130 to prolong battery lifetime. After ingestion of the capsule, the electromagnetic field emitted  
131 is monitored in real time by means of Bluetooth communication and stored within the

132 detector for later analysis by dedicated software. Capsules do not interfere with each other  
133 and up to three capsules can be followed simultaneously.

134           When the electromagnetic field is registered by the detector, data is converted  
135 into coordinates  $(x,y,z,\Phi,\theta)$  via an iterative algorithm. The  $x,y,z$  coordinates represent distance  
136 in the 3-dimensional planes, while the  $\Phi,\theta$  express the angular position of the capsule relative  
137 to the detector **and thereby the rotation of the capsule**. Thus, changes in position, velocity of  
138 movements, and orientation of the capsule can be studied with respect to anatomical  
139 information. Thereby, contractile activity and progression dynamics can be studied  
140 throughout the entire gastrointestinal tract. Artefacts due to breathing and posture changes  
141 are recorded by a thoracic belt and accelerometer inside the detector. Electromagnetic noise  
142 from the surrounding environment affects the capsule signal to the detector. Thus, the  
143 minimal distance allowable from external electronic devices (e.g. computers) is approximately  
144 40 centimetres. Further details about the system have been published previously<sup>21, 23</sup>.

145

#### 146 **Study protocol**

147 All subjects arrived at the research facility in the morning after an overnight fast. Prior to  
148 ingestion, the capsule was activated and the wireless connection between detector and  
149 capsule was confirmed. Study participants swallowed the capsule immediately after ingestion  
150 of a standardized meal and a glass of water. There were slight variations in the content and  
151 number of calories within the meal taken in the various studies (**Appendix B supplementary**  
152 **material**)<sup>21-26</sup>.

153           In the first 6 hour period following capsule and test meal ingestion, the subject  
154 was instructed not to consume any food and only a small quantity of water if required. After  
155 leaving the research facility, subjects were allowed to perform their normal daily routine and

156 activities, but hard physical work and sports were prohibited. Participants wore the detector  
157 belt at all times during the study, except when showering and changing clothes. The 3D-Transit  
158 system was worn until capsule expulsion or battery power expired.

159

## 160 **Intragastric movements**

161 The two investigators (NS and MWK) performing the data analysis were both very experienced  
162 in the practical use of the 3D-transit system, including use of the basic software and  
163 assessment of total and regional gastrointestinal transit times. To enable them to clear  
164 artefacts and mark contractions manually, they spent two days with the manufacturer in  
165 Switzerland. During that stay, they performed supervised analysis of data from approximately  
166 30 recordings.

167           Gastric emptying time was defined as time from ingestion to pyloric passage.  
168 The latter was determined by a combination of visual identification of the duodenal arch and  
169 a change in contraction pattern from 3 contractions/minute to 9-12 contractions/minute<sup>21, 27</sup>.

170           As described in a previous publication from our group, all fast capsule  
171 movements, physiological or non-physiological, were identified with an automated algorithm  
172 developed by Motilis Media SA. Fast capsule movements were defined as displacements  
173 longer than 4 cm with an average velocity of more than 4 cm/minute<sup>28</sup>. The majority of these  
174 would be artefacts. Such displacements were compared to data from the accelerometer to  
175 identify artefacts due to changes in body position. Very fast movements (>2 cm/second) or  
176 movements where the capsule returned to the exact same position the main characteristics  
177 of artefacts. Every single contraction of the stomach was manually marked to calculate its  
178 amplitude and the frequency (figure 1). The computation was done for the three-dimensional  
179 movement of the capsule as well as its rotation. Hence, surrogate markers for the amplitude

180 of gastric contraction were position amplitude, based on capsule movement in millimetres  
181 (mm) and rotation amplitude based on capsule rotation around its own axis in degrees (°).  
182 Furthermore, periods with clearly visible contractions were separated from those with  
183 uncertain or no contractions, thereby giving a percentage of time with detectable contractions  
184 in each subject. Unless the capsule had passed the pylorus earlier, the analysis of intragastric  
185 movements was restricted to first the 6 hours following the index meal.

186

### 187 **Statistical analysis**

188 Statistical analysis was performed in STATA15 (Stata Release 15, College Station, StataCorp  
189 LLC, TX, USA and SPSS Statistics Version 25, IBM, NY, USA). Because data were non-Gaussian,  
190 all analyses were non-parametric and data are presented as median and (range). A  
191 multivariate analysis was performed to explore associations between gastric emptying or  
192 contractions and demographics or the content of the standardized meal. Day-to-day variation  
193 for the 46 subjects who had ingested capsules on two consecutive days is given as coefficient  
194 of variation (difference/mean) and illustrated by Bland-Altman plot. The interobserver  
195 variation for 16 randomly chosen recordings is also given as coefficient of variation  
196 (difference/mean) and illustrated by Bland-Altman plots (figure 3),  $p < 0.05$  was considered  
197 statistically significant.

198

### 199 **Results**

200 Use of the 3D-Transit system was well tolerated without any adverse events or discomfort.  
201 From a total of 185 recordings from 132 healthy volunteers, 14 recordings (8%) from 7  
202 volunteers (5%) were discarded due to poor quality of data. Hence, recordings from 125  
203 volunteers (56 males and 69 females, median age of 39 years (20-88), median BMI of 24 (19-

204 41)) were available for further analysis. Among these, 46 subjects had ingested capsules on  
205 two consecutive days. In the 46 subjects who ingested two capsules, only the first recording  
206 was included as normative data and for analysis of association with background variables.  
207 During its stay in the stomach, the capsule was located in the antrum or corpus most of the  
208 time with a relatively quick passage through the fundus (example shown in figure 2). Gastric  
209 contractions were detectable for a median of 92% (5-100) of the time.

210

### 211 **Gastric emptying**

212 Median gastric emptying time was 2.7 hours (0.1 – 21). In 111 (89%) recordings, the capsule  
213 passed from the stomach to the duodenum during the 6 hours period following capsule  
214 ingestion with the standardized meal. We found no association between gastric emptying  
215 time and age, gender, BMI, calorie content or fat content of the test meal (all  $p > 0.05$ ).  
216 Normative values for gastric emptying and gastric contractions are shown in Table 1.

217

### 218 **Frequency of gastric contractions**

219 The median frequency of all gastric contractions was 3.1 per minute (2.6-3.9). The median  
220 frequency was lower in males (3.00 per minute (2.61-3.53)) than in females (3.16 per minute  
221 (2.70-3.80)) ( $p = 0.001$ ), but increased with age by 0.004 per year ( $p < 0.001$ ). Fat content, total  
222 number of calories of the meal and the BMI of the subject under study showed no associations  
223 with the frequency of gastric contractions (all  $p > 0.05$ ).

224

### 225 **Rotation and change in position of the capsule**

226 Median rotation amplitude was  $35^\circ$  (4-92) and median position amplitude was 11 mm (6-31).  
227 The rotation amplitude was higher in females (median  $40^\circ$  (14-85 $^\circ$ )) than in males (median  $30^\circ$

228 (4-77)) ( $p=0.001$ ) and decreased with increasing BMI ( $p=0.001$ ). It was not associated with age  
229 or the composition of the meal (all  $p>0.05$ ). The **position amplitude** decreased with age  
230 ( $p=0.008$ ), increased with the number of calories in the test meal ( $p=0.004$ ), but it was not  
231 affected by BMI, gender or composition of the meal ( $p>0.05$ ). Normative values for **rotation**  
232 **and change in position of the capsule** are shown in Table 1.

233

#### 234 **Day-to-day variation**

235 Comparing the recordings from capsules taken at two consecutive days ( $n=46$ ), there were no  
236 differences in gastric emptying, frequency of contractions, **rotation amplitude or position**  
237 **amplitude** (all  $p>0.05$ ). The median coefficient of variation (difference/mean) was 0.76 for  
238 gastric emptying, 0.04 for frequency of contractions, 0.34 for **rotation** amplitude, 0.28 for  
239 **position amplitude** and 0.17 for percentage of time with visible contractions.

240

#### 241 **Interobserver variation**

242 Comparing the 16 randomly chosen recordings assessed by two investigators (MWK and NS),  
243 there were no differences in contraction frequency, **rotation amplitude, position amplitude** or  
244 time with detectable contractions (all  $p>0.05$ ). The coefficient of variation was 0.01 for  
245 frequency of contractions, 0.06 for **rotation amplitude**, 0.07 for **position** amplitude, and 0.13  
246 for time with detectable contractions.

247 **Discussion**

248 **Main findings of the study**

249 In the present study, we found that the 3D-Transit system allows safe and ambulatory  
250 assessment of GE time and **assessment** of gastric contractions in healthy volunteers. Use of  
251 **the system was well tolerated and useful data was obtained** from 95% of subjects studied.  
252 Normative values for parameters of gastric motility were reported based on recordings from  
253 125 healthy subjects.

254

255 **Methods for description of gastric motility**

256 The pathophysiology behind gastroparesis is complicated and poorly understood. However,  
257 loss of interstitial cells of Cajal, disturbances in vagal function and neuropathy secondary to  
258 diabetes mellitus or neurodegenerative diseases may contribute<sup>29, 30</sup>. Gastric emptying  
259 scintigraphy is gold standard for assessment of gastric emptying. Gastric retention of >60% of  
260 the meal at 2 hours and/or >10% at 4 hours are criteria usually used to define gastroparesis<sup>1-</sup>  
261 <sup>10</sup>. However, the association between symptoms of gastroparesis and results from  
262 scintigraphy is disputed and especially the quality of the methodology is of significance for the  
263 outcome<sup>11, 30</sup>. Furthermore, scintigraphy is expensive and exposes the subject under study to  
264 radiation. It is also time consuming and can only be applied in a specialized hospital setting.  
265 Finally, information obtained by GE scintigraphy is limited to the stomach. This is a major  
266 limitation as many motility disorders are panenteric<sup>14</sup>. However, protocols can be modified  
267 for assessment of transit through the whole gut<sup>31, 32</sup>. Other methods include: (1) barium  
268 gastric x-ray, which is useful to exclude mechanical obstruction, but it does not provide  
269 quantitative information on gastric emptying; (2) electrogastrigraphy, which records gastric  
270 myoelectric activity by cutaneous electrodes on the anterior abdominal wall overlaying the

271 stomach. Recordings are defined as abnormal when dysrhythmia exceeds 30% of the  
272 recording time and/or when the ingestion of a meal fails to initiate or increase the amplitude  
273 of the signal<sup>33</sup>. However, electrogastrography provides no information on GE and there has  
274 never been widely uptake of the method. (3) The wireless motility capsule, which records  
275 pressure, pH and temperature during its passage through the gastrointestinal tract<sup>34-38</sup>The  
276 method is well-validated, it is easy to use and robust normative data for overall and regional  
277 transit times as well as measure of contractile activity are available <sup>34-36</sup>. However, the wireless  
278 motility capsule provides no information on the exact position of the capsule at a given point  
279 of time.

280

### 281 **Comparison of results from 3D-transit with those of other methods**

282 In the present study, median GE time of the 3D-Transit capsule was 2.7 hours. This is very  
283 close to results from the wireless motility capsule (where median gastric emptying was 3.2,  
284 3.23 and 3.25 hours<sup>21, 37, 38</sup> even though the size of the wireless motility capsule is significantly  
285 larger than the 3D-Transit capsule (3D-Transit capsule 8.3 x 21.5milimitres; wireless motility  
286 capsule 11.7 x 26.8 millimetres) <sup>37, 38</sup>.

287 In the stomach, slow wave contractions usually start in the fundus and spread  
288 towards the antrum. Their frequency has been described in detail, especially by  
289 electrogastrography and antro-duodenal manometry, and corresponds very well to the  
290 average 3.1 per minute frequency observed in the present study<sup>39, 40</sup>. Based on  
291 electrogastrography, contractions with a frequency <2 per minute have been used to define  
292 “bradygastria” while frequencies > 4 per minute have defined “tachygastria”. In the present  
293 study, the average frequency of contractions within a single subject ranged from 2.6 to 3.9.

294 Hence, none of our 125 healthy would be defined as having an abnormal frequency of gastric  
295 contractions<sup>41</sup>.

296 Data from electrogastronomy suggest that some patients with gastroparesis  
297 have a reduced amplitude of gastric contractions<sup>41</sup>. The amplitude of contractions assessed  
298 with 3D-Transit is not directly comparable to the amplitude determined by  
299 electrogastronomy. We do however consider the **position amplitude, determined by**  
300 **movement, or the rotation amplitude of** a capsule within the stomach a more direct measure  
301 than the amplitude of an electrical signal registered on the surface of the abdomen.

302 In the present study, GE time was not associated with age, gender, BMI or the  
303 minor differences in the composition of the meal given with the capsule. Hence, we consider  
304 our normative data on gastric emptying robust. **In contrast**, the contraction frequency of 3.1  
305 per minute *was* affected by gender and **age while position and rotation amplitudes** were  
306 associated with gender, BMI and calorific content of the meal. This has to be considered when  
307 future studies with the 3D-Transit system are designed.

308

### 309 **Pan-enteric assessment**

310 Motility disorders are usually not confined to one region of the gastrointestinal tract. A major  
311 advantage with the wireless motility capsule and the 3D-Transit system is that they allow  
312 ambulatory assessment of whole gut and regional gastrointestinal transit times. This is  
313 important both for research and in a clinical setting. Compared to the wireless motility  
314 capsule, the major advantage with the 3D-Transit system is that it defines the precise location  
315 and orientation of the capsule within the gastrointestinal tract. This allows for assessment of  
316 segmental colonic transit times and details on progression through the colon<sup>28, 42, 43</sup>. Based on  
317 region-specific contraction frequencies and anatomical characteristics, previous studies have

318 compared regional transit times in healthy subjects and various patient groups<sup>21-27, 44</sup> .  
319 Recently, data analysis has been refined to allow detailed assessment of colonic motility  
320 patterns<sup>28, 42</sup>. As shown in the present study, the same investigations can now be further  
321 analysed to provide details on gastric motility. Future studies will show whether description  
322 of gastric contractions will add clinically relevant information to gastric emptying time.

323

#### 324 **Limitations**

325 Gastric motility patterns depend on whether the subject is in the fasting or the postprandial  
326 state. Usually, an object with the dimensions of the 3D-Transit capsule will pass the pylorus in  
327 the fasting state during phase III of the migrating motor complex<sup>40</sup>. We aimed to study gastric  
328 motility and define normative values during a 6 hours post-ingestion period before *ad libitum*  
329 feeding was allowed. This was only partially achieved as 10% of capsules remained in the  
330 stomach at the end of the 6 hours. Hence, we restricted the analysis of gastric contractions to  
331 data obtained before subjects were allowed to eat again after 6 hours. The same was not  
332 possible for the gastric emptying time which may have been prolonged when subjects were  
333 allowed to eat freely. Studies with electrogastrigraphy have shown that the frequency and  
334 amplitude of gastric contractions increase shortly after a meal<sup>41</sup>. This may have caused some  
335 variation in our data on contractility because the GE time, and thereby the recording time  
336 after the meal, varied considerably.

337 **We do not know exactly how the signal amplitude of either rotation or change**  
338 **in position of the capsule reflect the true amplitude of gastric contractions. Hence, we have**  
339 **chosen to use the terms “rotation amplitude” and “position amplitude”. The definition of**  
340 **pyloric passage included a combination of change in contraction frequency and identification**  
341 **of the highly characteristic fast movement through the duodenal arch. This includes some**

342 subjective assessment. We have previously validated pyloric passage defined by magnet  
343 tracking against the same determined with PillCam and found that agreement was very  
344 good<sup>27</sup>.

345 In accordance other methods for assessment of gastrointestinal motility, we  
346 found that that intersubjective and day-to-day variation were large for all parameters studied.  
347 This was especially true for gastric emptying time. Even though the large variation most likely  
348 reflects normal physiology, it may prove a limitation for the future use of the method as a  
349 diagnostic tool. Further studies are needed to determine whether 3D-Transit and the  
350 parameters of gastric contractility described in the present study will prove more sensitive  
351 than existing methods in distinguishing patients with various motility disorders from healthy  
352 subjects. Another limitation with use of the 3D-Transit system is the manual analysis of the  
353 recordings which is time-consuming and may depend on the experience of the investigator.  
354 The latter is probably of minor consequence as we found that interobserver variation was  
355 small.

356

### 357 **Conclusions**

358 In conclusion, the present study adds normative data on gastric contractility patterns and  
359 emptying time to those on region-specific transit times and motility patterns in the colon  
360 already available for the Motilis 3D-Transit system. Given the impact of age, gender and BMI,  
361 any future clinical study may have to take these into account and match patients accordingly.

362

363 **ACKNOWLEDGEMENTS, FUNDING AND DISCLOSURES**

364 *Declaration of Personal Interests:* Vincent Schlageter is the co-owner of Motilis Medica SA.

365 All other authors have no conflicts of interest to declare.

366 *Declaration of funding interests:*

367 Aarhus, Denmark: studies were supported by The Parkinson's Disease Foundation, Denmark,

368 The Foundation of July 2, 1984, Denmark, The Lundbeck Foundation and The Novonordisk

369 Foundation. London, United Kingdom: research was supported by Queen Mary University of

370 London through in-house departmental funds; Aalborg, Denmark: Researchers were

371 indirectly funded from their research and training positions;

372

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375 *Author contributions:* Nanna Sutter: Collation of data, data analysis, statistical analysis,

376 interpretation of data, drafting of the manuscript; Mette W Klinge: Data analysis and

377 acquisition, revised the manuscript for important intellectual content. Esben Bolvig Mark:

378 Development of algorithms for data analysis, revised the manuscript for important intellectual

379 content; Anne-Mette Haase, Jakob Poulsen, Karoline Knudsen, Per Borghammer and

380 Gursharan Nandhra: Data acquisition, revised the manuscript for important intellectual

381 content. Vincent Schlageter: Technical support, revised the manuscript for important

382 intellectual content; Malcolm Birch, Mark Scott, Asbjørn Mohr Drewes and Klaus Krogh: Study

383 concept and design, study supervision, interpretation of data, critical revision of the

384 manuscript for important intellectual content. All authors approved the final version of the

385 manuscript.

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520

## 521 **Tables**

522 **Table 1**

	Median	Range	Percentiles				
			5%	25%	75%	90%	95%*
<b>Gastric emptying time (all) n=125 (hours)</b>	2.7	0.1-21.2	0.6	2.0	4.1	5.8	8.7*
Male (n= 56)	2.9	0.1-8.4	0.6	2.1	4.0	5.1	5.8*
Female (n=69)	2.6	0.1-21.2	0.6	2.0	4.1	6.1	16.8*
Age 40 years or less (n=65)	2.7	0.1-21.2	0.6	1.9	4.6	5.8	15.6*
Age above 40 years (n=62)	2.7	0.1-17.6	1.3	2.0	4.0	5.8	6.1*
<b>Frequency of gastric contractions (per minute)</b>	3.1	2.6-3.8	2.8	2.9	3.2	3.4	3.5
Male	3.0	2.6-3.5	2.8	2.9	3.1	3.2	3.3

Female	3.2	2.7-3.8	2.8	3.0	3.3	3.4	3.5
Age 40 years or less	3.0	2.8-3.4	2.8	2.9	3.2	3.3	3.3
Age above 40 years	3.1	2.6-3.8	2.8	3.0	3.3	3.5	3.5
<b>Rotation amplitude</b> (degrees)	35	4-85	15	26	47	58	65
Male	30	4-77	14	23	40	48	61
Female	40	14-85	21	27	53	62	69
Age 40 years or less	34	13-85	21	26	48	64	69
Age above 40 years	35	4-70	15	26	46	54	58
<b>Position amplitude</b> (millimeters)	11	6-31	7	9	14	16	18
Male	11	6-31	7	9	14	16	18
Female	11	7-26	8	9	13	16	18

Age 40 years or less	11	8-26	8	10	14	17	19
Age above 40 years	10	6-31	7	9	13	15	18

523

524 **Table 1.** Normative values for parameters of gastric motility assessed with the  
 525 electromagnetic 3D-Transit capsule system. \*The upper 95 percentile for gastric emptying  
 526 includes recordings from subjects in whom the capsule had not passed the pylorus within the  
 527 6 hours after its ingestion with the standardized meal, and who were allowed ad libitum  
 528 feeding hereafter.

529