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**Personal care plans and glycaemic control: the role of body mass index and physical activity**

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1        Personal care plans and glycaemic  
2        control: the role of body mass index  
3                    and physical activity

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## 22 **ABSTRACT**

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### 24 **Background**

25 Although BMI (body mass index) and physical activity are implicated in diabetes  
26 complications, it is unclear how these factors influence personalised care planning linked to  
27 glycaemic control. This study assessed the mediating effects of BMI and physical activity on  
28 relations between personalised care plans (PCPs) and glycated haemoglobin (HbA<sub>1c</sub>) levels,  
29 using population-based data.

30

### 31 **Method**

32 Bootstrapping was used to analyse PCP, HbA<sub>1c</sub>, BMI, and physical activity data from 3894  
33 respondents to the 2014 Health Survey for England, for whom HbA<sub>1c</sub> data was available,  
34 regardless of diabetes status. This group comprised 1812 (46.5%) males, 17 and 2082  
35 (53.5%) females, aged 16 to 90 (Mean = 51.68 years, SD = 17.25).

36

### 37 **Results**

38 Patients with a PCP had higher HbA<sub>1c</sub> levels compared to those without a care plan. BMI  
39 influenced this relationship amongst patients aged 40 to 60; those with a PCP and higher  
40 HbA<sub>1c</sub> also tended to have higher BMI values. Physical activity did not affect the relationship  
41 between PCPs and glycaemic control.

42

### 43 **Conclusions**

44 BMI, but not physical activity, partly explained higher HbA<sub>1c</sub> levels in patients with a PCP.  
45 Given recent population-based evidence implicating exercise in diabetes complications, some

46 debate is needed on the role of physical activity in personalised care planning and glycaemic  
47 control.

48

49 **KEY POINTS**

- 50 • Patients with a PCP (personal care plan) have higher HbA<sub>1c</sub> values.
- 51 • BMI partly explains higher HbA<sub>1c</sub> levels in patients with a PCP.
- 52 • Physical activity is not implicated in the relationship between PCPs and HbA<sub>1c</sub> levels.
- 53 • Given that population-based prospective evidence implicates physical activity in  
54 diabetes-related complications, there is need for some debate on the role of physical  
55 activity in personalised care planning and glycaemic control.

56

57

58 **Key words**

59 Personal care plan; glycaemic control; BMI; physical activity

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61 **Acknowledgements**

62 The author wishes to thank the UK Data Service for making the HSE data available

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## 71 **INTRODUCTION**

72 Blood glucose control is a critical aspect of diabetes care (Jia, 2016). People with diabetes, or  
73 individuals experiencing hyperglycaemia (Godoy et al., 2012, Farrokhi et al., 2011) may be  
74 offered *personal care plans* (PCPs) (Coulter et al., 2013) to help them manage their blood  
75 glucose (Diabetes UK, 2009). A PCP usually consists of a written document outlining  
76 specific goals, and activities designed to achieve these objectives (Diabetes UK, 2009,  
77 Coulter et al., 2013, The Health Developer Network, 2016). PCPs reflect a partnership  
78 between the doctor/nurse and their patients (Diabetes UK, 2017), are essential for effective  
79 self-management (Jansen et al., 2015, Tarkin et al., 2008), and have been implicated in  
80 improved patient outcomes (Hird et al., 2015, Russell et al., 2008).

81 PCPs are presumed to play an important role in HbA<sub>1c</sub> (glycated haemoglobin) levels  
82 (Diabetes UK, 2009). Setting clear goals for glycaemic control (e.g., achievable HbA<sub>1c</sub>  
83 targets), and designating specific actions to attain these objectives (e.g., weekly participation  
84 in a local sports programme), can help patients initiate and sustain key lifestyle changes  
85 essential for reducing HbA<sub>1c</sub> (Coulter et al., 2013). A recent Cochrane review of the effects of  
86 personalised care planning in adults with long-term conditions found HbA<sub>1c</sub> levels to be  
87 0.24% lower in patients with a PCP, compared to those receiving usual care (Coulter et al.,  
88 2015). Thus, HbA<sub>1c</sub> level is an important criterion that GPs consider in deciding which  
89 patients to offer a PCP (Diabetes UK, 2017).

90 In 2015 Diabetes UK launched an ‘Information Prescription’ scheme to ensure  
91 diabetes patients who fail to meet HbA<sub>1c</sub>, blood pressure and cholesterol targets receive a  
92 one-page PCP containing specific action plans for improving metabolic control (e.g.,  
93 reducing dietary fat, performing 150 minutes of moderate aerobic activity per week, and  
94 strength exercises  $\geq 2$  days per week) (Diabetes UK, 2017, Diabetes UK, 2015a). Patients  
95 with high blood pressure, high total cholesterol-to-HDL (high density lipoprotein) ratios, and

96 high HbA<sub>1c</sub> have a greater risk of developing complications, and hence are likely to benefit  
97 from personalised care (Diabetes UK, 2017). Information prescriptions are integrated into  
98 primary care IT systems, such as EMIS Web, so that GPs receive an automated alert if a  
99 specific patient is failing to meet their metabolic targets (Diabetes UK, 2015b). Diabetes UK  
100 literature suggests over 1000 diabetes patients a month use information prescriptions to  
101 manage their condition (Diabetes UK, 2015a). Information prescriptions can be considered a  
102 specific IT-based PCP designed to improve glycaemic control in diabetes patients with a high  
103 risk of complications (Diabetes UK, 2015a).

104         Glycaemic control is influenced by BMI (body mass index) and physical activity  
105 (Malnick and Knobler, 2006, Hu et al., 2014, Bhupathiraju and Hu, 2016, Gay et al., 2016,  
106 Cuenca-Garcia et al., 2012, Hamer et al., 2014). Lower BMI values are associated with better  
107 HbA<sub>1c</sub> outcomes (Patiakas and Charalampous, 2010, Senechal et al., 2013, Diels et al., 2014).  
108 For example, one study of type 2 diabetes patients found that a decrease in waist  
109 circumference, and increased physical fitness, was associated with an increased likelihood of  
110 significant HbA<sub>1c</sub> reductions (> 0.5%) (Senechal et al., 2013). A prospective study of data  
111 from a 1958 birth cohort revealed that early onset of overweight/obesity was implicated in a  
112 23.9-fold increased risk of a HbA<sub>1c</sub> value  $\geq$  7% (Power and Thomas, 2011). An investigation  
113 of 2707 adults at risk from type 2 diabetes implicated higher amounts of moderate-to-  
114 vigorous physical activity in lower HbA<sub>1c</sub> values (Gay et al., 2016). Moderate-to-vigorous  
115 has been found to predict improved metabolic outcomes, including HbA<sub>1c</sub> levels, in healthy  
116 adults (Hamer et al., 2014).

117         BMI and physical activity affect the risk of complications in diabetes patients (Segula,  
118 2014, Blomster et al., 2013). For example, obesity (i.e., BMI  $\geq$  30) is strongly implicated in  
119 cardiovascular disease (Wilson et al., 2002), high blood pressure (Segula, 2014), and higher  
120 levels of LDL cholesterol (Varbo et al., 2015). Physical inactivity has been linked to impaired

121 renal function, increasing retinopathy, and other complications, in patients with type 1  
122 diabetes (Waden et al., 2008). Evidence from a long-term prospective study of over 11,000  
123 patients with type 2 diabetes found that moderate-to-vigorous levels of physical activity (of at  
124 least 15 minutes per week) at baseline was associated with a reduced incidence of  
125 cardiovascular events, microvascular complications, and mortality rates, over a 5-year period  
126 (Blomster et al., 2013).

127         Despite evidence implicating BMI/physical activity in HbA<sub>1c</sub> levels (Senechal et al.,  
128 2013, Quirk et al., 2014), and diabetes complications (Blomster et al., 2013, Waden et al.,  
129 2008, Segula, 2014), it is unclear the extent to which these factors influence the relationship  
130 between PCPs and glycaemic control (Diabetes UK, 2017). Although BMI and physical  
131 activity are not part of the criteria for offering information prescriptions to patients, (Diabetes  
132 UK, 2015a), they nevertheless constitute key lifestyle changes recommended for lowering  
133 HbA<sub>1c</sub> in personalised care planning (Diabetes UK, 2009, Diabetes UK, 2015a). Thus, it  
134 follows that HbA<sub>1c</sub> reductions associated with having a PCP will be partly attributable to  
135 changes in BMI and/or levels of physical activity. Similarly, poor weight control, and/or  
136 failure to adhere to physical activity targets, may negative the influence of PCPs on  
137 glycaemic control.

138         Nurses typically form part of health care teams who work in partnership with patients  
139 to arrange and monitor PCPs (Coulter et al., 2013), including information prescriptions  
140 (Diabetes UK, 2015b, Diabetes UK, 2017). Guidance published by Diabetes UK makes  
141 provision for a health professional to be named on information prescriptions, with a statement  
142 specifically inviting patients to discuss and agree achievable HbA<sub>1c</sub> targets with a doctor or  
143 nurse (Diabetes UK, 2015a). There is particular emphasis on controlling HbA<sub>1c</sub> levels, in  
144 order to reduce the risk of complications (Diabetes UK, 2015a). Prescriptions makes specific  
145 reference to lifestyle factors, meaning patient consultations are likely to involve

146 conversations about BMI/physical activity, in relation to glycaemic control (Diabetes UK,  
147 2015a). As both BMI and physical activity contribute significantly to HbA<sub>1c</sub>, and related  
148 complications (Segula, 2014, Bhupathiraju and Hu, 2016, Blomster et al., 2013), it is  
149 essential to better understand how these factors influence the relationship between PCPs and  
150 HbA<sub>1c</sub> levels (Diabetes UK, 2015a).

151

## 152 AIM

153 This study had two objectives. The first was to establish the association between PCPs and  
154 HbA<sub>1c</sub> levels. Current literature suggests HbA<sub>1c</sub> can be both a precursor and outcome of  
155 PCPs. In the former scenario HbA<sub>1c</sub> level is used as a criterion for offering PCPs to patients  
156 (Diabetes UK, 2015a, Diabetes UK, 2015b). In the latter situation, PCPs can help patients  
157 lower their HbA<sub>1c</sub> level (Coulter et al., 2015). Both directions of causality are valid. For the  
158 purposes of this paper, PCP status (i.e., whether or not a patient has a PCP) was treated as the  
159 ‘predictor’ variable, and HbA<sub>1c</sub> as the ‘outcome’ measure. This is consistent with a primary  
160 objective of personalised care – to improve glycaemic control (Coulter et al., 2015) – but  
161 does not preclude the use of HbA<sub>1c</sub> as a basis for offering PCPs to patients (Diabetes UK,  
162 2015a, Diabetes UK, 2017). The second objective was to determine the extent to which BMI  
163 and physical activity explain any relationship between PCPs and HbA<sub>1c</sub> levels.

164 It was expected that (a) patients with PCPs will have lower HbA<sub>1c</sub> levels compared to  
165 patients who had not agreed a care plan, and (b) BMI and physical activity will be implicated  
166 in this relationship, as mediating factors, such that the relationship between PCPs and HbA<sub>1c</sub>  
167 is partly explained by BMI and physical activity. Thus, for example, lower HbA<sub>1c</sub> values in  
168 patients with a PCP may partly reflect lower BMI scores, and/or greater physical activity  
169 levels in such patients. These hypotheses were tested both prior to and following adjustments  
170 for selected covariates, including diabetes status.



171 **METHOD**

172

173 *Sample and procedure*

174 This study analysed data on PCP status, HbA<sub>1c</sub>, BMI, and physical activity, obtained from the  
175 2014 *Health Survey for England* (HSE), an annual exercise that assesses health-related  
176 parameters and lifestyle factors in children and adults (Health Survey for England, 2014).

177 The survey is commissioned by the Health and Social Care Information Centre, and consists  
178 of an interview (including self-administered questionnaires), followed by a visit by a nurse to  
179 collect biomedical data. The 2014 survey was completed by 8,077 adults (aged 16 and over),  
180 and over 2000 children (aged 0 to 15). The study reported here analysed data from 3894  
181 adults for whom HbA<sub>1c</sub> data was available. This group comprised 1812 (46.5%) males, and  
182 2082 (53.5%) females, aged 16 to 90 (Mean = 51.68 years, SD = 17.25). The sample (92%)  
183 was predominantly Caucasian.

184

185 *Measures*

186 *Glycated haemoglobin* (HbA<sub>1c</sub>) was based on non-fasting blood samples, and (for this  
187 study) calibrated in mmol/mol. HbA<sub>1c</sub> data provides a measure of average blood glucose  
188 levels over the previous three months (Jia, 2016).

189 *PCP* status was assessed via two questions. Firstly, respondents were asked if (a) they  
190 had ever had a PCP-related discussion with a doctor/nurse regarding a long-term condition,  
191 'Yes' (1)/ 'No or not sure' (0); and (b) whether they had agreed a PCP with a health  
192 professional during the past 12 months, 'no PCP agreed' (0)/ 'agreed a PCP < or > 12 months  
193 ago' (1). Responses to both items were combined to form a PCP index, with a higher  
194 indicating a better PCP status (e.g., discussed and/or agreed a PCP).

195            *Physical activity* was measured using the short IPAQ (International Physical Activity  
196 Questionnaire) (Booth, 2000). The IPAQ/Short assesses three activity levels – *walking*,  
197 *moderate-intensity*, and *vigorous-intensity* – across several domains (leisure time,  
198 domestic/gardening, work/transport-based). Respondents receive a score for each level,  
199 reflecting a summation of duration (minutes) and frequency (days). For the purposes of this  
200 study, six separate scores were evaluated: total number of minutes usually spent per *day*, and  
201 in the last 7 *days*, doing (a) ‘vigorous-intensity’ activities, (b) ‘moderate-intensity’ activities,  
202 and (c) walking.

203            *BMI* was computed by dividing weight in kilograms by the square of height in metres  
204 ( $\text{kg/m}^2$ ) (Nuttall, 2015). Adults (aged > 16) were classified into the following groups: Less  
205 than 18.5 ‘Underweight’; 18.5 to less than 25 ‘Normal’; 25 to less than 30 ‘Overweight’; 30  
206 or more ‘Obese’; 40 or more ‘Morbidly obese’. The present study evaluated raw BMI scores,  
207 for the purposes of hypotheses testing, and BMI groups (excluding the underweight category,  
208 and combining obese and morbidly obese groups) for descriptive statistics.

209            Other variables assessed included blood pressure, and diabetes status. *Blood pressure*  
210 was assessed using the Omron HEM 907 blood pressure monitor. Respondents were  
211 classified into three groups: BP under 130/80, BP under 140/90, but not under 130/80, and  
212 BP over 140/90. Respondents also indicated whether they had been diagnosed with high  
213 blood pressure by a doctor; ‘Yes’ (1), ‘No’ (2). *Diabetes status* was assessed by asking  
214 respondents if they currently have or have ever had diabetes, ‘Yes’ (1)/ ‘No’ (0).

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Insert Table 1 about here  
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224 Insert Table 3 about here

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## 230 **RESULTS**

231 Descriptive statistics (means/SD) are presented in *Table 1*. PCP data was available for 42.7%  
 232 (n = 1662) respondents. The vast majority of this subgroup (87.7%) had *not* agreed a PCP  
 233 with a health professional, while the remainder (12.3%) had agreed a PCP with a  
 234 doctor/nurse,  $\leq$  or  $\geq$  12 months ago. These groups did not differ on measures physical activity  
 235 (both groups achieved the recommended  $\geq$  150 minutes of moderate-intensity activity), BMI  
 236 score (both groups classified as ‘Overweight’), mental wellbeing score, or gender  
 237 distribution. There were also no group differences in the proportion who had been diagnosed  
 238 with high blood pressure by a doctor/nurse (over 98% of respondents had received this  
 239 diagnosis), and the proportion receiving earnings from employment or self-employment.  
 240 However, patients who had agreed a PCP were slightly younger, more likely to have been  
 241 diagnosed with diabetes, and had higher blood glucose levels (HbA<sub>1c</sub>).

242 *Table 2* shows the bivariate associations between variables. Patients who had  
 243 discussed and agreed a PCP with their doctor were younger, generated higher HbA<sub>1c</sub> values,  
 244 more likely to have been diagnosed with diabetes, and performed fewer minutes of moderate-

245 intensity physical activity during the previous 7 days. In addition to denoting diabetes status,  
246 higher HbA<sub>1c</sub> values were associated with greater BMI, and fewer minutes of physical  
247 activity per day/week. Higher BMI values also depicted older age, doctor-diagnosed HBP,  
248 having ever had diabetes, and fewer minutes of physical activity. Gender differences are also  
249 noteworthy: overall, females had lower blood pressure, and lower levels of light (i.e.,  
250 walking), moderate-, and vigorous-intensity physical activity per day, and during the past 7  
251 days.

252 Hypothesis testing was performed using a bootstrapping SPSS dialogue (Hayes, 2013,  
253 Hayes, 2009). Bootstrapping was performed separately for each of the following age-related  
254 subgroups: aged up to 39; over 40; over 50; and over 60. In each bootstrapping model HbA<sub>1c</sub>  
255 (mmol/mol) was entered as the outcome ('Variable Y'), while PCP status was treated as the  
256 predictor ('Variable X'). BMI and the six IPAQ/physical activity levels, were treated as  
257 mediator variables ('Variables M'). Diabetes status (whether participants had ever had  
258 diabetes), blood pressure (doctor-diagnosed), and gender, were treated as control variables  
259 (i.e., covariates). The conservative Sobel test was used to determine mediation. Results are  
260 shown in *Tables 3 and 4*.

261 *0 to 39 years.* PCP status directly predicted glycaemic control, such that people who  
262 had agreed a PCP had higher HbA<sub>1c</sub> values compared to those without a PCP. Neither BMI  
263 nor physical activity mediated this relationship.

264 *Over 40 years.* PCP status directly predicted HbA<sub>1c</sub>; patients with a PCP tended to  
265 have poorer glycaemic control. This relationship was mediated by BMI, whereby patients  
266 who had a care plan had both higher BMI and higher HbA<sub>1c</sub> values, compared to those  
267 without a plan. This depicted a mediator effect because greater BMI was also associated with  
268 higher HbA<sub>1c</sub> levels (see *Figure 1*). This indirect effect was significant based on the  
269 conservative Sobel test ( $z = 2.15, p < 0.05$ ), and accounted for 13.1% of the total effect of

270 PCP status on HbA<sub>1c</sub>. Controlling for diabetes status and other covariates attenuated the  
271 indirect effect (Sobel test  $p > 0.05$ ), but did not completely abolish it (see *Table 3*).

272 *Over 50 years.* Having a PCP was associated with higher HbA<sub>1c</sub> levels in this group.  
273 This association was mediated by BMI, whereby those with a care plan had higher BMI, and  
274 poorer glycaemic control, compared to people without a PCP (see *Figure 2*). The Sobel test  
275 for this indirect effect was significant ( $z = 2.06, p < 0.05$ ). The mediator effect accounted for  
276 18.2% of the total effect of PCP status on HbA<sub>1c</sub>. Adjusting for covariates weakened but did  
277 not entirely negate the indirect effect (*Table 3*).

278 *Over 60 years.* Although having a PCP predicted higher HbA<sub>1c</sub> values, neither BMI  
279 nor physical activity mediated this relationship.

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281 Insert Figure 1 about here

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## 286 **DISCUSSION**

287 Contrary to what was hypothesised patients with a PCP had higher HbA<sub>1c</sub> levels. However,  
288 higher BMI scores partly explained this relationship (see *Figures 1 and 2*). Previous research  
289 has implicated BMI in elevated HbA<sub>1c</sub> (Power and Thomas, 2011, Senechal et al., 2013,  
290 Patiakas and Charalampous, 2010). Interestingly, there was no evidence implicating physical  
291 activity in PCP – HbA<sub>1c</sub> relations, despite previous studies associating exercise with  
292 glycaemic control (Umpierre et al., 2011, Gay et al., 2016, Hamer et al., 2014).

293 Previous research has implicated PCPs in *lower* HbA<sub>1c</sub> (Coulter et al., 2015). An obvious  
294 explanation for the higher HbA<sub>1c</sub> levels observed here is the mediating effect of BMI. It is

295 possible PCPs may lead to elevated HbA<sub>1c</sub> values, if patients are gaining weight, perhaps due  
296 to noncompliance with PCP targets or action plans, and/or other factors, such poor doctor-  
297 patient interaction (Paternotte et al., 2015). Previous research shows a strong connection  
298 between higher BMI scores and higher HbA<sub>1c</sub>, with one study linking elevated BMI scores in  
299 childhood to a 23.9-fold increased risk of a HbA<sub>1c</sub>  $\geq$  7% later in life (Power and Thomas,  
300 2011). Thus, patients with high HbA<sub>1c</sub>/BMI stand to benefit considerably from information  
301 prescriptions (Diabetes UK, 2015a) and other forms of personalised care (Coulter et al.,  
302 2013) that specifically target weight control. The fact that BMI mediated the PCP – HbA<sub>1c</sub>  
303 relationship specifically in 40 to 60 year olds suggests BMI plays a particularly important  
304 role in personalised care and glycaemic control in middle-aged patients (Owen et al., 2015).

305 Another possible explanation for the higher HbA<sub>1c</sub> levels in patients with PCPs is that  
306 care plans tend to be offered to patients with poorer glycaemic control (Diabetes UK, 2015a).  
307 Offering PCPs to people with higher HbA<sub>1c</sub> reflects current recommendations that  
308 information prescriptions should target individuals at high risk of complications (i.e., high  
309 HbA<sub>1c</sub>) (Diabetes UK, 2017). The mediating effect of BMI may simply reflect the fact that  
310 patients with high HbA<sub>1c</sub> also tend to have high BMI scores (Power and Thomas, 2011),  
311 and/or that GPs are simply more likely to offer PCPs to patients exhibiting both risk factors  
312 (Diabetes UK, 2009).

313 The fact that physical activity did not affect relations between PCPs and HbA<sub>1c</sub> is  
314 worrying given that inactivity significantly increases the risk of complications (Waden et al.,  
315 2008, Blomster et al., 2013). Evidence from a long-term prospective study associates  
316 moderate-to-vigorous levels of activity with a reduced risk of cardiovascular problems,  
317 microvascular complications, and premature mortality (Blomster et al., 2013). Although other  
318 research suggests no link between exercise and complications (Makura et al., 2013), the  
319 availability of population-based prospective data (Blomster et al., 2013) suggests physical

320 inactivity should be an important factor in personalised care planning and glycaemic control.  
321 This seems particularly relevant to middle-aged/older patients. This demographic may find  
322 moderate-to-vigorous intensity exercises (e.g., fast cycling, running) particularly challenging,  
323 especially if conducted on a regular basis (Sparling et al., 2015), negating the glycaemic  
324 benefits (Kennedy et al., 2013). Other factors, such as increased calorie intake, or variations  
325 in insulin dosage, may also attenuate the effect of physical activity on HbA<sub>1c</sub>, and should be  
326 carefully explored by doctors and patients when setting up PCPs (Kennedy et al., 2013).

327         This study has some limitations. Firstly, while BMI mediated the PCP – HbA<sub>1c</sub>  
328 association, BMI is a poor index of body fat, or morbidity and mortality risk (Nuttall, 2015).  
329 Another problem is that data analysis did not control for every covariate relevant to PCP  
330 status, BMI, and HbA<sub>1c</sub> (e.g., dietary intake, or insulin resistance). Additionally, there is  
331 uncertainty regarding the actual content of PCPs agreed with patients in this data set; due to  
332 the personalised nature of PCPs, the HSE does include individual HbA<sub>1c</sub> targets, or  
333 recommended lifestyle changes. Furthermore, the HSE data analysed here pre-dates the  
334 launch of information prescriptions by Diabetes UK (Diabetes UK, 2015b). As this new  
335 personalised care tool is IT-based and can be deployed in a matter of minutes (Diabetes UK,  
336 2017), it's impact on glycaemic control may be more dramatic than more generic PCP  
337 formats (Coulter et al., 2013). Finally, the cross-sectional nature of the design precludes  
338 inferences about the possible direction of causality.

339         This is the first study to examine how BMI and physical activity influence relations  
340 between personalised care planning and glycaemic control (Diabetes UK, 2017). The study  
341 suggests BMI partly explains higher HbA<sub>1c</sub> levels in patients with a PCP. The irrelevance of  
342 physical activity in this context is worrying given recent population-based prospective  
343 evidence implicating exercise intensity in diabetes complications (Blomster et al., 2013).  
344 These findings are particularly important given the current emphasis on the use of

345 information prescriptions to improve patient outcomes (Diabetes UK, 2015b). If physical  
346 activity level is a precursor for complications (Blomster et al., 2013), then there needs to be  
347 some debate amongst doctors/nurses, in partnership with patients, on the role of exercise in  
348 personalised care regarding glycaemic control.

349

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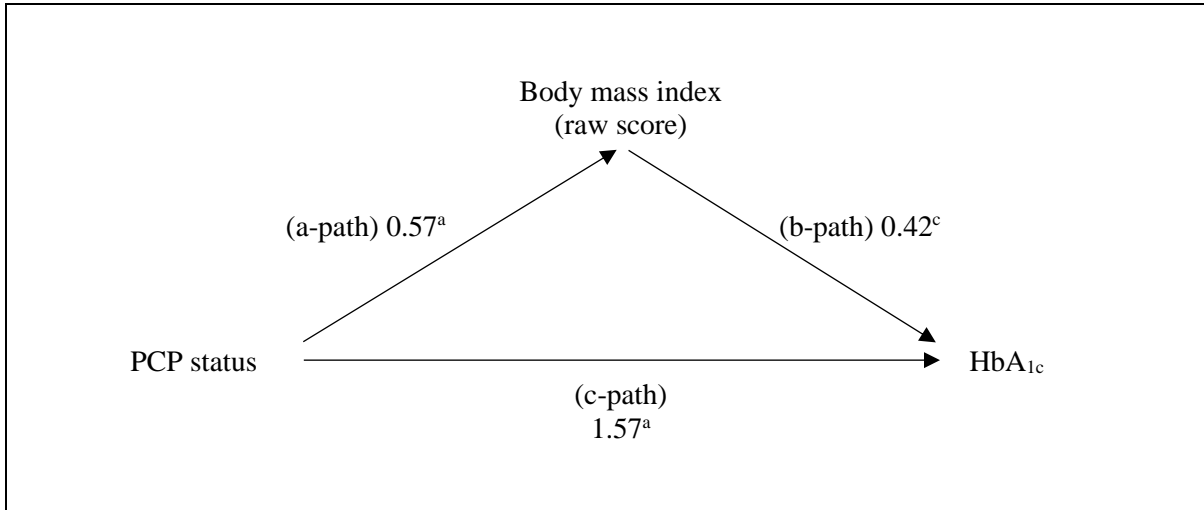
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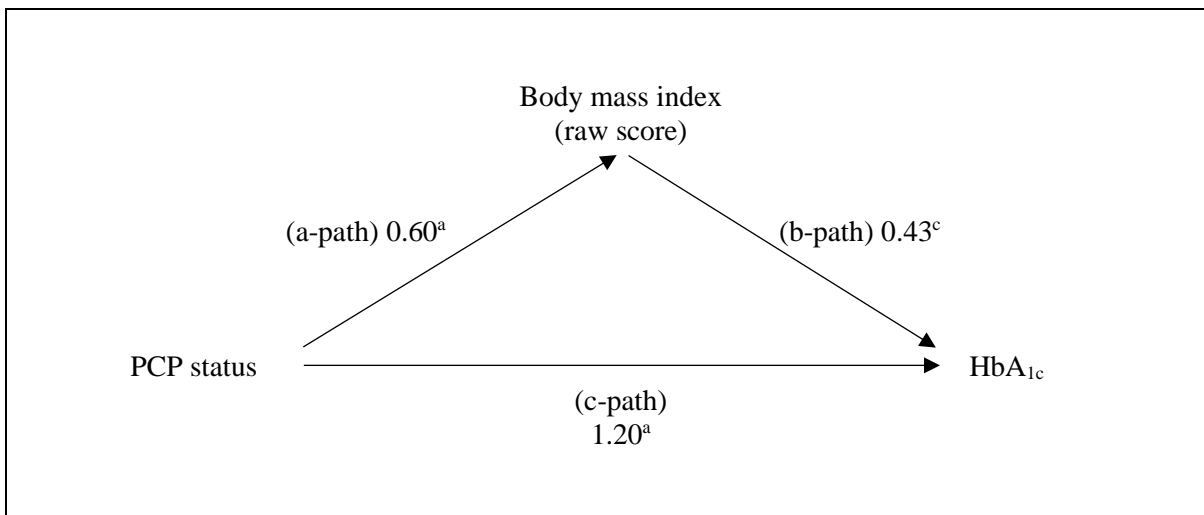
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**Figure 1** Mediating effect of BMI on the PCP – HbA<sub>1c</sub> association in patients aged ≥ 40  
(<sup>a</sup> $p < 0.05$ , <sup>c</sup> $p < 0.01$ , <sup>b</sup> $p < 0.001$ )

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**Figure 2** Mediating effect of BMI on the PCP – HbA<sub>1c</sub> association in patients aged ≥ 50  
(<sup>a</sup> $p < 0.05$ , <sup>c</sup> $p < 0.01$ , <sup>b</sup> $p < 0.001$ )

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506 Table 1 – *Descriptive statistics by PCP status.*

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Variables	PCP status		P
	No PCP agreed	Agreed PCP < or > 12 months ago	
Sample size (%)	1458 (87.7%)	204 (12.3%)	
Age	57.85 (16.87)	55.08 (15.94)	$t(1660) = 2.25, p < 0.05$
Gender (Male/Female)	638 (86.8%)/820 (88.5%)	97 (13.2%)/107 (11.5%)	Not Significant
HbA <sub>1c</sub> (mmol/mol)	39.67 (10.32)	42.07 (13.98)	$t(1660) = -2.36, p < 0.05$
BMI (Body mass index)	28.52 (5.52)	29.13 (6.05)	Not Significant
Diabetes status (currently have, or ever had diabetes) (Yes/No)	172 (11.8%)/1284 (88.2%)	37 (18.1%)/167 (81.9%)	$\chi(1) = 6.50, p < 0.01$
High blood pressure – doctor diagnosed (Yes/No)	585 (98%)/12 (2%)	82 (98.8%)/1 (1.2%)	Not Significant
Minutes VPA per day	57.62 (106.13)	52.20 (104.47)	Not Significant
Minutes MPA per day	64.00 (103.14)	50.33 (85.31)	Not Significant
Minutes Walking per day	78.18 (99.62)	85.04 (118.45)	Not Significant
Minutes VPA per week	214.06 (542.67)	217.42 (578.30)	Not Significant
Minutes MPA per week	279.64 (581.86)	212.51 (482.57)	Not Significant
Minutes Walking per week	424.20 (624.99)	456.83 (749.69)	Not Significant

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Figures show the mean (+ standard deviation) or count (+ percentage). PCP = Personal care plan (status); MPA = Moderate-intensity activity; VPA = Vigorous-intensity activity; BMI = Body mass index.

522 Table 2 Bivariate correlations and descriptive statistics

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
<b>1) PCP index</b>	-													
<b>2) Age</b>	-0.057 <sup>a</sup>	-												
<b>3) Gender (M/F)</b>	-0.037	0.011	-											
<b>4) Hb<sub>A1c</sub> mmol/ml</b>	0.088 <sup>b</sup>	0.297 <sup>b</sup>	-0.016	-										
<b>5) HBP (doctor)</b>	-0.002	0.381 <sup>b</sup>	-0.034 <sup>a</sup>	0.255 <sup>b</sup>	-									
<b>6) Diabetes (Y/N)</b>	0.086 <sup>b</sup>	0.165 <sup>b</sup>	-0.022	0.599 <sup>b</sup>	0.203 <sup>b</sup>	-								
<b>7) BMI score</b>	0.047	0.163 <sup>b</sup>	-0.029	0.249 <sup>b</sup>	0.225 <sup>b</sup>	0.178 <sup>b</sup>	-							
<b>8) VPA min p/d</b>	-0.025	-0.111 <sup>b</sup>	-0.177 <sup>b</sup>	-0.030	-0.071 <sup>b</sup>	-0.038 <sup>a</sup>	-0.049 <sup>b</sup>	-						
<b>9) MPA min p/d</b>	-0.041	-0.074 <sup>b</sup>	-0.135 <sup>b</sup>	-0.053 <sup>b</sup>	-0.063 <sup>b</sup>	-0.061 <sup>b</sup>	-0.026	0.474 <sup>b</sup>	-					
<b>10) WK min p/d</b>	0.012	-0.104 <sup>b</sup>	-0.075 <sup>b</sup>	-0.057 <sup>b</sup>	-0.082 <sup>b</sup>	-0.033	-0.057 <sup>b</sup>	0.345 <sup>b</sup>	0.361 <sup>b</sup>	-				
<b>11) VPA min p/w</b>	-0.029	-0.096 <sup>b</sup>	-0.173 <sup>b</sup>	-0.023	-0.063 <sup>b</sup>	-0.041 <sup>a</sup>	-0.034 <sup>a</sup>	0.907 <sup>b</sup>	0.454 <sup>b</sup>	0.340 <sup>b</sup>	-			
<b>12) MPA min p/w</b>	-0.057 <sup>a</sup>	-0.075 <sup>b</sup>	-0.131 <sup>b</sup>	-0.039 <sup>a</sup>	-0.052 <sup>b</sup>	-0.047 <sup>b</sup>	-0.010	0.443 <sup>b</sup>	0.905 <sup>b</sup>	0.368 <sup>b</sup>	0.485 <sup>b</sup>	-		
<b>13) WK min p/w</b>	0.002	-0.111 <sup>b</sup>	-0.073 <sup>b</sup>	-0.062 <sup>b</sup>	-0.086 <sup>b</sup>	-0.036 <sup>a</sup>	-0.059 <sup>b</sup>	0.345 <sup>b</sup>	0.369 <sup>b</sup>	0.945 <sup>b</sup>	0.360 <sup>b</sup>	0.404 <sup>b</sup>	-	
<b>14) ≥ 30 min of MPA/VPA p/wk</b>	-0.020	-0.225 <sup>b</sup>	-0.106 <sup>b</sup>	-0.171 <sup>b</sup>	-0.155 <sup>b</sup>	-0.116 <sup>b</sup>	-0.138 <sup>b</sup>	0.420 <sup>b</sup>	0.431 <sup>b</sup>	0.164 <sup>b</sup>	0.311 <sup>b</sup>	0.335 <sup>b</sup>	0.156 <sup>b</sup>	-

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Note. HBP (High Blood Pressure), BMI (Body Mass Index), VPA (Vigorous-intensity physical activity), MPA (Moderate-intensity physical activity), WK (Walking), p/d (per day), p/w (per week). HBP reflects doctor-diagnosed cases. All physical activity variables denote total number of minutes spent on the specified activity. Superscripts: <sup>a</sup> $p < .05$ , <sup>b</sup> $p < .01$ , <sup>c</sup> $p < .001$ .



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541Table 3 – *Mediating effects of BMI and physical activity on the PCP – HbA<sub>1c</sub> association, before and after adjusting for diabetes status and other covariates.*

Regression pathways	Age groups							
	0-39		Over 40		Over 50		Over 60	
	Effect	(CI)	Effect	(CI)	Effect	(CI)	Effect	(CI)
<b>Total effect of PCP on HbA<sub>1c</sub></b>	1.58 <sup>a</sup>	(0.34, 2.82)	1.84 <sup>a</sup>	(0.87, 2.81)	1.46 <sup>a</sup>	(0.39, 2.52)	1.60 <sup>a</sup>	(0.45, 2.74)
<b>Direct effect of PCP on HbA<sub>1c</sub></b>	1.53 <sup>a</sup>	(0.28, 2.78)	1.57 <sup>a</sup>	(0.62, 2.53)	1.20 <sup>a</sup>	(0.15, 2.24)	1.48 <sup>a</sup>	(0.37, 2.59)
<b>Indirect effect of PCP on HbA<sub>1c</sub> via;</b>								
Minutes VPA per day	0.03	(-0.16, 0.64)	-0.02	(-0.18, 0.02)	-0.03	(-0.22, 0.03)	-0.00	(-0.23, 0.05)
Minutes MPA per day	-0.28	(-0.84, 0.02)	0.06	(-0.02, 0.23)	0.05	(-0.01, 0.26)	-0.01	(-0.23, 0.04)
Minutes Walking per day	0.18	(-0.03, 1.16)	0.00	(-0.11, 0.31)	0.00	(-0.09, 0.18)	-0.01	(-0.24, 0.04)
Minutes VPA past week	-0.01	(-0.48, 0.22)	-0.01	(-0.14, 0.05)	-0.01	(-0.20, 0.04)	-0.00	(-0.15, 0.08)
Minutes MPA past week	0.29	(-0.02, 0.72)	-0.00	(-0.13, 0.13)	-0.01	(-0.19, 0.09)	0.00	(-0.05, 0.12)
Minutes Walking past week	-0.18	(-1.01, 0.03)	-0.00	(-0.26, 0.12)	-0.00	(-0.10, 0.07)	-0.01	(-0.18, 0.06)
BMI (body mass index)	0.02	(-0.10, 0.23)	0.24 <sup>a</sup>	(0.03, 0.48)	0.26 <sup>a</sup>	(0.05, 0.56)	0.17	(-0.08, 0.49)

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<sup>a</sup> $p < 0.05$  or CI range excludes '0'. PCP = Personal care plan (status) ; MPA = Moderate-intensity activity ; VPA = Vigorous-intensity activity. BMI = Body mass index. For simplicity the table does not include the effects of variable  $X$  (PCP) on variables  $M$  (physical activity, BMI), and effects of variables  $M$  on variable  $Y$  (HbA<sub>1c</sub>).

547 Table 4 – *Mediating effects of BMI on the PCP – HbA1c association, before and after adjusting for diabetes status and other covariates.*

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Regression pathways	Age groups			
	Over 40		Over 50	
	Effect	CI	Effect	CI
<i>Total effect of PCP on HbA<sub>1c</sub></i>	0.78 <sup>a</sup>	(0.02, 1.54)	0.72	(-0.12, 1.58)
<i>Direct effect of PCP on HbA<sub>1c</sub></i>	0.71	(-0.05, 1.47)	0.66	(-0.18, 1.52)
<i>Indirect effect of PCP on HbA<sub>1c</sub> via;</i>				
BMI (body mass index)	0.07 <sup>a</sup>	(0.00, 0.18)	0.09 <sup>a</sup>	(0.01, 0.25)

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<sup>a</sup> $p < 0.05$  or CI range excludes '0'. Lower confidence interval for the BMI effect in the 'over 40 group' exceeded zero (0.003). For simplicity only the significant mediator variable (BMI) is included here; the table does not include the other *M* variables.

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