Aims The association of psychosocial and physical factors with health outcome in patients with congestive heart failure (CHF) has not been fully explored. The aim of this study was to assess the physical and mental health in relationship to health outcome in post-infarction patients with advanced left ventricular dysfunction.

Methods and results A total of 1058 patients enrolled in the Multicenter Automatic Defibrillator Implantation Trial II (MADIT II) completed the Medical Outcome Trust Short Form (SF-12) at baseline. Physical component summary (PCS) and mental component summary (MCS) of SF-12 were analysed in relationship to survival, hospitalization due to CHF, and implantable cardioverter-defibrillator (ICD) therapy. Both baseline PCS and MCS were significantly associated with death ($P < 0.001$ and $P < 0.016$, respectively) and hospitalization due to CHF ($P < 0.001$). After adjustment for significant clinical covariates and treatment group, low PCS and low MCS groups remained significant predictors of mortality and CHF hospitalization. Neither PCS nor MCS was associated with appropriate ICD therapy for ventricular tachyarhythmias. Patients who experienced appropriate ICD shocks had a statistically significant deterioration of PCS but not MCS from baseline to 12 months.

Conclusion Lower baseline PCS and MCS are associated with unfavourable health outcome in MADIT II patients, but not with appropriate ICD therapy for ventricular tachyarrhythmias. Patients who experience ICD shock reported a decrease in PCS, but little or no changes in MCS.
study we also evaluated changes in patients’ self-report physical functioning and mental health in response to ICD shocks.

Methods
Study population
The objectives and design of the MADIT II have been previously reported in detail. In brief, MADIT II enrolled 1232 patients, age 21 and greater without upper cut-off, with prior myocardial infarction and severe left ventricular dysfunction (EF < 30%). Patients were randomly assigned to implanted cardioverter-defibrillator therapy (ICD, n = 742) or conventional therapy (n = 490) with optimal pharmacological treatment (high usage of beta-blockers, ACE-inhibitors, statins) in both groups. The Medical Outcome Trust Short Form (SF-12) was distributed at baseline, than in months 3, 12, 24, and close-out. For the current analysis, we used available data for 1058 patients at the baseline (enrolment), and for 627 patients at 12-month follow-up (excluding those who died, were less than 1 year in the trial, or did not fill out the survey at 12 months).

Physical and mental health assessment
At the time of enrolment, several demographic and clinical characteristic data were collected. Baseline information assessing HRQoL was obtained before the patient knew the results of randomization to ICD or conventional therapy. The SF-12 is a generic measure of health status, encompassing 12 questions covering eight dimensions of health significantly affected by medical condition: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. The eight-scale profile has been reduced to the two widely validated summary measures, but is less accurate for eight-scale profile. The norm-based scoring system allows for simple interpretation, instead of relying on data-driven functional forms. The hazard ratios for continuous variables were estimated for each 10-point decrease (~1 SD) in PCS and MCS. Any baseline characteristic (Table 1) with P < 0.10 were eligible for entry into a stepwise regression procedure to develop one set of covariates for the endpoints: death, CHF hospitalization, and HF hospitalization or ICD therapy).

Endpoint analysis
The baseline MCS and PCS were analysed in regard to the following endpoints: death, hospitalization due to CHF, and death or CHF hospitalization, whichever occurs first, since this combined outcome is frequently used as primary endpoint in CHF trials. Because the endpoint of CHF hospitalization is not inclusive of death, patients who die during follow-up without experiencing the endpoint of CHF hospitalization are censored when analysing CHF as a separate endpoint. We also evaluated the relationship between baseline physical and mental health and ICD therapy (antitachycardia pacing or shocks) for ventricular tachyarrhythmias in patients in the ICD arm. The analysis of ICD therapy included retrospective evaluation of reported discharges in response to sustained ventricular tachycardia (VT) or ventricular fibrillation (VF).

Additionally, we analysed the impact of ICD shocks on PCS and MCS over 12 months of follow-up. The appropriate shocks (ICD shock delivered for the treatment of ventricular tachyarrhythmias) were categorized in three groups based on the number of episodes terminated by shocks (0, 1, ≥2).

Statistical analysis
On the basis of the baseline PCS and MCS scores distribution, all study subjects were assigned to either the ‘low’ group (PCS or MCS value equal or below population median) or the ‘high’ group (PCS or MCS scores above median). Baseline clinical characteristics were compared between groups using the χ2 test or Fisher’s exact test when appropriate. Kaplan-Meier curves were used to illustrate time to event for the various endpoints. Multivariable Cox proportional hazards regression models for both dichotomized and continuous versions of PCS and MCS were developed to determine their association with endpoints while controlling for relevant covariates and for randomization. Dichotomized and continuous versions of PCS and MCS were pre-specified to avoid bias and provide for a relatively simple interpretation, instead of relying on data-driven functional forms. The hazard ratios for continuous variables were estimated for each 10-point decrease (~1 SD) in PCS and MCS. Because we used the significance level of 0.05 as the cutoff for selection into the final models, any covariates, which were in the final models, had a significant independent contribution to the prediction of at least one of the endpoints of interest. To test the proportional hazards assumption, regression models were fit, which included the interaction terms for each covariate with survival time. The linearity assumption for continuous PCS and MCS was tested using Cox proportional hazards regression models with PCS and MCS cut into quartiles. The hazard ratios for continuous variables were estimated for each 10-point decrease (~1 SD) in PCS and MCS. Any baseline characteristic (Table 1) with P < 0.10 were eligible for entry into a stepwise regression procedure to develop one set of covariates for the endpoints: death, CHF hospitalization, and HF hospitalization or ICD therapy.

Results
Association of PCS and MCS with baseline clinical characteristics
For all study subjects, the mean ± SD baseline PCS score was 36 ± 10 with a median equal to 35. The mean MCS score was 50 ± 10 with a median of 53. SF-12 data were available for 638 patients randomized to ICD group and 420 to conventional therapy group. There were no statistically significant differences in the mean baseline PCS and MCS values when stratified by treatment arm (conventional or ICD therapy).

There were 529 patients with PCS score < 35, classified as ‘low’ PCS group. They were younger, more likely to be female, and smokers compared with patients with higher scores (Table 1). In addition, patients in the ‘low’ score group were more likely to have a history of non-CABG revascularization, diabetes, angina, NYHA class II–IV, poorer EF, faster resting heart rate, lower blood pressure, higher BMI, and lower use of lipid-lowering agents. There was no difference in the use of beta-blockers between ‘low’ or ‘high’ score groups of PCS component. The low PCS group was more frequently treated with digitalis and diuretics.
Patients with MCS score <53, classified as 'low' MCS group were younger, had greater representation of female gender, white race, hypertension requiring treatment, diabetes, angina, NYHA class II–IV, faster resting heart rate, lower systolic blood pressure, and lower use of beta-blockers and lipid-lowering agents in comparison with patients having higher scores.

Association of baseline PCS and MCS with endpoints

The cumulative probability of death, stratified by the median cut points for both PCS and MCS is shown in Figure 1. Patients with a baseline PCS score below the median had a mortality rate twice as high as patients with a PCS score above the median. The rate of mortality was also significantly higher in the 'low' MCS group than in the 'high' score group. The 'low' PCS score group had a higher probability of CHF hospitalization (Figure 2) compared with patients with a higher level of PCS. Similar findings were observed for MCS score. When death and CHF hospitalization were considered as a composite endpoint, both low PCS and low MCS were significantly associated with a higher risk of this combined outcome (Figure 3).

After adjustment for significant clinical covariates (age, gender, EF, CHF NYHA class, BUN level, resting heart rate) and randomization group (ICD vs. conventional therapy), the multivariable Cox proportional hazards regression models revealed an increase in the risk of mortality risk of 89% in the 'low' PCS group and of 42% per 10-unit decrease in the PCS measured continuously (Table 2). There was an increase in the risk of mortality of 39% in the 'low' MCS group and of 21% per 10-unit decrease in the continuous MCS score. Both PCS and MCS contributed significantly to the risk of hospitalization for CHF in patients with scores below median as well as when analysed as continuous variables per 10-unit decrease in score (75 and 42%; 36 and 24%, respectively). The association was even more evident when the combined endpoint of CHF hospitalization or death was analysed.

**Table 1** Baseline clinical characteristics of MADIT II study population according to PCS and MCS

<table>
<thead>
<tr>
<th>Clinical variables</th>
<th>PCS Low</th>
<th>PCS High</th>
<th>P-value</th>
<th>MCS Low</th>
<th>MCS High</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICD treatment</td>
<td>314 (59)</td>
<td>324 (61)</td>
<td>0.530</td>
<td>323 (61)</td>
<td>315 (60)</td>
<td>0.615</td>
</tr>
<tr>
<td>Death</td>
<td>110 (21)</td>
<td>55 (10)</td>
<td>&lt;0.001</td>
<td>99 (19)</td>
<td>66 (12)</td>
<td>0.005</td>
</tr>
<tr>
<td>CHF hospitalization</td>
<td>140 (27)</td>
<td>78 (15)</td>
<td>&lt;0.001</td>
<td>129 (25)</td>
<td>89 (17)</td>
<td>0.003</td>
</tr>
<tr>
<td>CHF hospitalization or death</td>
<td>198 (38)</td>
<td>107 (20)</td>
<td>&lt;0.001</td>
<td>183 (35)</td>
<td>122 (23)</td>
<td>0.001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>63.55±10.63</td>
<td>65.37±10.26</td>
<td>0.005</td>
<td>63.40±10.71</td>
<td>65.52±10.14</td>
<td>0.001</td>
</tr>
<tr>
<td>Females</td>
<td>107 (20)</td>
<td>61 (12)</td>
<td>&lt;0.001</td>
<td>103 (20)</td>
<td>65 (12)</td>
<td>0.001</td>
</tr>
<tr>
<td>White race</td>
<td>453 (86)</td>
<td>463 (87)</td>
<td>0.367</td>
<td>433 (82)</td>
<td>483 (91)</td>
<td>0.001</td>
</tr>
<tr>
<td>Cigarette smoking anytime</td>
<td>443 (84)</td>
<td>412 (78)</td>
<td>0.013</td>
<td>429 (81)</td>
<td>426 (81)</td>
<td>0.864</td>
</tr>
<tr>
<td>Non-CABG revascularization</td>
<td>252 (48)</td>
<td>219 (42)</td>
<td>0.033</td>
<td>248 (48)</td>
<td>223 (42)</td>
<td>0.102</td>
</tr>
<tr>
<td>Coronary bypass surgery</td>
<td>298 (56)</td>
<td>321 (61)</td>
<td>0.151</td>
<td>296 (56)</td>
<td>321 (61)</td>
<td>0.092</td>
</tr>
<tr>
<td>Hypertension requiring treatment</td>
<td>296 (56)</td>
<td>266 (51)</td>
<td>0.074</td>
<td>299 (57)</td>
<td>263 (50)</td>
<td>0.026</td>
</tr>
<tr>
<td>Diabetes</td>
<td>227 (43)</td>
<td>140 (27)</td>
<td>0.001</td>
<td>199 (38)</td>
<td>168 (32)</td>
<td>0.048</td>
</tr>
<tr>
<td>Months after MI</td>
<td>76.51±72.90</td>
<td>86.85±83.24</td>
<td>0.114</td>
<td>73.31±72.62</td>
<td>89.95±82.92</td>
<td>0.004</td>
</tr>
<tr>
<td>Angina pectoris</td>
<td>191 (37)</td>
<td>97 (19)</td>
<td>&lt;0.001</td>
<td>163 (31)</td>
<td>125 (24)</td>
<td>0.008</td>
</tr>
<tr>
<td>CHF NYHA class II–IV</td>
<td>372 (72)</td>
<td>281 (54)</td>
<td>&lt;0.001</td>
<td>360 (69)</td>
<td>293 (56)</td>
<td>0.001</td>
</tr>
<tr>
<td>EF (%)</td>
<td>22.67±5.48</td>
<td>23.36±5.36</td>
<td>0.045</td>
<td>22.71±5.61</td>
<td>23.32±5.22</td>
<td>0.108</td>
</tr>
<tr>
<td>BUN (mg/dL)</td>
<td>24.26±13.76</td>
<td>22.72±10.48</td>
<td>0.664</td>
<td>23.91±13.45</td>
<td>23.07±10.92</td>
<td>0.721</td>
</tr>
<tr>
<td>Heart rate (b.p.m.)</td>
<td>74.02±16.02</td>
<td>71.60±15.41</td>
<td>0.009</td>
<td>74.86±15.96</td>
<td>70.79±15.30</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>120.04±18.21</td>
<td>122.86±18.20</td>
<td>0.012</td>
<td>120.34±18.73</td>
<td>122.56±17.70</td>
<td>0.048</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>69.88±10.80</td>
<td>71.20±10.79</td>
<td>0.046</td>
<td>70.15±10.87</td>
<td>70.94±10.74</td>
<td>0.234</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.54±5.64</td>
<td>27.76±4.84</td>
<td>0.015</td>
<td>28.02±5.58</td>
<td>28.28±4.94</td>
<td>0.417</td>
</tr>
<tr>
<td>Beta blockers</td>
<td>329 (62)</td>
<td>335 (63)</td>
<td>0.703</td>
<td>308 (58)</td>
<td>356 (67)</td>
<td>0.002</td>
</tr>
<tr>
<td>Calcium channel blockers</td>
<td>79 (15)</td>
<td>59 (11)</td>
<td>0.068</td>
<td>71 (13)</td>
<td>67 (13)</td>
<td>0.715</td>
</tr>
<tr>
<td>Digitalis</td>
<td>341 (65)</td>
<td>291 (55)</td>
<td>0.002</td>
<td>325 (61)</td>
<td>307 (58)</td>
<td>0.259</td>
</tr>
<tr>
<td>ACE-Inhibitors</td>
<td>418 (79)</td>
<td>395 (75)</td>
<td>0.094</td>
<td>399 (75)</td>
<td>414 (78)</td>
<td>0.274</td>
</tr>
<tr>
<td>Diuretics</td>
<td>425 (80)</td>
<td>372 (70)</td>
<td>&lt;0.001</td>
<td>402 (76)</td>
<td>395 (75)</td>
<td>0.618</td>
</tr>
<tr>
<td>Lipid-lowering drugs</td>
<td>338 (64)</td>
<td>369 (70)</td>
<td>0.043</td>
<td>328 (62)</td>
<td>379 (72)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Plus-minus values are number and means ± SD. All categorical data are expressed as number (%). 'Low' = median; 'High' = media.
Figure 1 Cumulative probability of death stratified by median cutoff values of baseline PCS and MCS. See Supplementary material online for a colour version of this figure.

Figure 2 Cumulative probability of hospitalization for CHF by median cutoff values of baseline PCS and MCS. See Supplementary material online for a colour version of this figure.

Figure 3 Cumulative probability of hospitalization for CHF or death, whichever occurs first, by median cutoff values of baseline PCS and MCS. See Supplementary material online for a colour version of this figure.

Figure 4 Probability of VT or VF therapy by median cutoff values of baseline PCS and MCS. See Supplementary material online for a colour version of this figure.
months was 53 vs. 53 at baseline. Secondly, we focused on the impact of ICD shocks on both PCS and MCS in those randomized to the ICD group who received ICD implants. There were 42 appropriate ICD shocks reported within the evaluated 12-month period. Patients who experienced appropriate ICD shocks reported significant changes in their physical health (Figure 5) against those who did not have an appropriate shock (−3.4 vs. 1.4, \(P = 0.003\)). This result maintained significance even after further adjustment for CHF hospitalization in this 12-month follow-up period. There was not statistically significant difference in the MCS score among patients who experienced appropriate shocks vs. the no-appropriate shocks group (\(P = 0.647\)). The number of shocks (0, 1, ≥2) was not significantly associated with 12-month changes from baseline MCS score (\(P = 0.287\)).

There were 33 inappropriate shocks reported. The mean changes in PCS and MCS among patients who experienced inappropriate shocks vs. patients without inappropriate shocks were not statistically significant (PCS = 0.6 vs. 0.8, respectively; \(P = 0.890\); MCS = 1.3 vs. −0.47, respectively; \(P = 0.467\)). Neither PCS nor MCS was significantly affected by antitachycardia pacing (13 episodes).

**Discussion**

The findings of the current study showed that the patients’ perception of their declining general health is associated with a high risk of both death and hospitalization due to CHF. The study population consisted of patients after myocardial infarction occurred on average 5 years before enrollment with majority of them presenting with CHF symptoms. The mean value for PCS score in our population was 36 ± 10, and this value is much lower than PCS score reported for healthy subjects (50 ± 10), indicating significant limitation in the daily activities as a result of disease process and its consequences in MADIT II patients. Decreased PCS values reflected limitations in self-care, physical activities, bodily pain, frequent tiredness, advanced grade of heart failure and left ventricular dysfunction that is consistent with clinical indicators for a decompensated heart. Among the ‘low’ PCS score group, 47% of the patients had EF < 25%, nearly 70% NYHA class ≥II, and 38% had BUN greater than 25 mg/dL, which are independent risk factors for mortality. The mean MCS score at baseline was comparable with a mean reported for healthy subjects (50 ± 10). Nevertheless, there was a significant association between the decrease in mental health and outcomes. After adjustment for significant clinical covariates including gender, age, EF, NYHA class, BUN level, resting heart rate, and treatment group, patients who presented psychological distress, social and role disability due to emotional problems were at high risk of death and they were more frequently admitted to hospitals due to worsening of CHF.

Surprisingly, neither PCS nor MCS were associated with incidence of VT/VF. To explore this concern, we analysed the predictive value of PCS and MCS for non-sudden (non-arrhythmic) death as well as for sudden death. We found that PCS was associated with non-sudden death (\(P < 0.001\)) but not with sudden death (\(P = 0.294\)). Thus, PCS and MCS are associated with pump failure death rather than with sudden death, and the self-reported
health concerns are more related to symptoms triggered by pump failure than arrhythmias. Additionally, patients studied were on average at 5 years after myocardial infarction and their psychological state might have been affected by persistent distress. Surawicz et al. suggested that there is a little relationship between SCD and psychological stress. Moreover, Kamarck and Jennings advocated that cardiac arrhythmias have been shown to be associated with intense emotional experience rather than chronic distress. Our results might suggested that SF-12 might be more sensitive to detect chronic distress, more likely contributing to non-sudden cardiac death, rather than acute process leading to sudden cardiac death.

Among survivors at 12 months, there was no significant difference in MCS and PCS between ICD group and conventionally treated group, indicating that having an ICD does not influence those scores. However, patients experiencing appropriate shocks, in comparison to the no-shock group, declared significant impairment in the PCS score most likely driven by the worse heart failure condition requiring treatment of the life-threatening arrhythmias. Mental health did not change significantly within 12 months of follow-up in patients experiencing shocks. In our study, we did not find an association between the number of shocks and the mental health. Moreover, patients requiring antitachycardia pacing therapy did not report any changes in either PCS or MCS. This finding may suggest that in MADIT II population, acceptance of the ICD device was high and its contribution to saving lives was well understood despite the concern that there might be electrical discharge.

Additionally, the occurrence of appropriate ICD shock is usually not perceived by patients who are frequently unconscious at the time of shock due to a delayed delivery of this painful therapy. Hypothetically, this aspect plus reassurance about life-saving properties of ICD might have contributed to lack of changes in MCS in our patients.

The physical functioning and mental health were evaluated in recently published studies. Similar to our findings, Rodriguez-Artalejo et al. in their prospective study of 394 CHF patients linked both worse PCS and MCS score with higher frequency of hospitalization and death in patients with heart failure. Newman et al. found an improvement in HRQoL over 6-month follow-up in patients with ICD therapy for atrial fibrillation and found no decrease in HRQoL in patients who experienced shock compared with the no-shock group. Results from the Patient Atrial Shock Survey of Acceptance and Tolerance (PASSAT) Study indicated that patients were more likely to accept ICD therapy for AF if they had greater HRQoL and less psychological distress.

However, in the Antiarrhythmics Vs. Implantable Defibrillators (AVID) trial, in which the occurrence of sporadic ICD shocks was associated with significant impairment in HRQoL, the development of ≥1 shock was associated with significant declines in both physical functioning and mental well-being. Additionally, Whang et al. published data indicating that more severe symptoms of depression significantly predicted appropriate ICD shocks.

The physical functioning and mental health, measured by self-reported questionnaires, provide information regarding patient’s physical, mental, and overall health in response to medical conditions. The personal and subjective insight involved in quality-of-life assessment might contribute to somewhat different findings regarding this issue.

The limitation of this study includes interpretation of the SF-12 score. Despite the fact that both PCS and MCS scales are a well-validated measure of physical, mental, and overall health, it does not allow determination of the relative contribution of specific psychological factors like depressive symptoms or disorders, anxiety, and personality characteristics that impact self-rated perception of physical and mental health. The PCS may be also influenced by the patient’s tendency to underreport symptoms, associated with negative effect rather than poorer quality of life. Hence, caution must be exercised while interpreting the psychological assessment score.

The assessment of the impact of ICD therapy on PCS and MCS during long-term follow-up was limited to the survivors group. Patients who did not have data at 12-month follow-up were older, had greater BMI, more likely to have AF and conduction abnormalities, more often treated with digitalis, and calcium channel blockers. They were twice likely to die and less likely to have ICD therapy for VT/VF and successful shocks. Patients who died or did not fill out the form at the 12th month of follow-up visit were excluded from the analysis limiting its statistical power. Particularly, the latter group refusing to participate in the study might be associated with a poorer baseline physical and mental health. Nevertheless, our cohort of 390 ICD patients who provided PCS and MCS at baseline and at 12th month was relatively large when compared with published data. Lack of differences in the mean scores between baseline and 12-month follow-up visit even in this selected cohort carries an important message that, on average, there is no significant decline in studied quality of life measures. Simultaneously, within the same cohort we observed that patients who experience appropriate ICD shocks had a decrease in PCS, which could be attributed to a progression of the disease, which subsequently could lead to arrhythmic events. There was no evidence to claim that ICD therapy contributed to lower PCS, since both inappropriate ICD shocks and antitachycardia pacing did not affect PCS.

Patients after myocardial infarction with advanced left ventricular dysfunction are at high risk for life-threatening ventricular arrhythmias leading to sudden cardiac death. Severity of the disease and its chronic course has substantial impact on their life and involves different coping strategies in adjustment for life-saving benefits of an ICD and distress emotions in response to electrical discharge. The population of patients with advanced heart failure treated with ICD therapy is growing and the information from our study can be used to identify patients’ health needs and subsequently provide better management and improve health outcome. Further studies, however, using disease-specific tool and specific measures examining selected psychological symptoms and disorders, in this particular population, will give us an opportunity to better understand their relationship to health outcome and better target treatment including psychological support and coping strategies.

**Supplementary material**

Supplementary material is available at *European Heart Journal* online.
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Conflict of interest: none declared.

References