

**Vitamin E status and quality of life in the elderly:
influence of inflammatory processes.**

Lucile Capuron, Aurélie Moranis, Nicole Combe, Florence Cousson-Gélie,
Dietmar Fuchs, Véronique De Smedt-Peyrusse, Pascale Barberger-Gateau,
Sophie Layé

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1 **Short Communication**

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4 **Vitamin E Status and Quality of Life in the Elderly:**
5 **Influence of Inflammatory Processes**
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10 Lucile Capuron¹, Aurélie Moranis¹, Nicole Combe², Florence Cousson-Gélie³, Dietmar Fuchs⁴,
11 Véronique De Smedt-Peyrusse¹, Pascale Barberger-Gateau⁵, Sophie Layé¹
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14
15 ¹ Laboratory of Psychoneuroimmunology, Nutrition and Genetics (PSYNUGEN), INRA 1286 –
16 University Victor Segalen Bordeaux 2, CNRS 5226, 146 rue Léo Saignat, Bordeaux, F-33076
17 France;

18 ² ITERG, University Bordeaux 1, Avenue des Facultés, Talence, F-33405, France;

19 ³ Laboratory of Psychology ‘Health and Quality of Life’ EA 4139, University Victor Segalen
20 Bordeaux 2, 3 Ter Place de la Victoire, Bordeaux, F-33076, France;

21 ⁴ Division of Biological Chemistry, Biocenter, Innsbruck Medical University, Innsbruck, Austria;

22 ⁵ Inserm, U897, University Victor Segalen Bordeaux 2, Bordeaux, F-33076 France
23

24
25 **Address for correspondence:** Dr Lucile Capuron, Laboratory of Psychoneuroimmunology,
26 Nutrition and Genetics (PSYNUGEN), INRA 1286 – University Victor Segalen Bordeaux 2, CNRS
27 5226, 146 rue Léo Saignat, Bordeaux, F-33076 France.

28 Email: lucile.capuron@bordeaux.inra.fr
29

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33 **Key Words:** vitamin E, aging, inflammation, quality of life
34

Abstract

Chronic low grade inflammation is a characteristic of aging that may lead to alterations in health status and quality of life. In addition to intrinsic biological factors, recent data suggest that poor nutritional habits may largely contribute to this condition. The present study aimed at assessing mental and physical components of quality of life and at determining their relationship to vitamin E status, inflammation and tryptophan (TRP) metabolism in the elderly. Sixty-nine elderly subjects recruited from the Three-City (3C) cohort study participated in the study. Quality of life was assessed using the medical outcomes study (MOS) 36-item short-form health survey (SF-36). Biological assays included the measurement of plasma vitamin E (alpha-tocopherol), inflammatory markers, including interleukin (IL)-6 and C reactive protein (CRP), and TRP metabolism. Results showed that participants with poor physical health status, as assessed by the SF-36, exhibited lower circulating concentrations of alpha-tocopherol together with increased concentrations of inflammatory markers. Similarly, poor mental health scores on the SF-36 were associated with lower concentrations of alpha-tocopherol, but also with decreased concentrations of TRP. These findings indicate that nutritional status, notably as it relates to vitamin E, is associated with immune function and quality of life in the elderly.

55 Introduction

56

57 Impaired quality of life, associated with mood and physical symptoms, is frequent in the
58 elderly. Approximately 7-40% of older persons report mental dysfunctions, especially in the form
59 of mood and cognitive alterations, and these contribute considerably to their social and occupational
60 dysfunction^(1,2). With the growing elderly population, there is a risk of a recrudescence of aged-
61 related behavioural symptoms and reduced wellbeing. Thus, the promotion of healthy lifestyles and
62 the prevention of impaired quality of life in the elderly represent a major public health concern.

63 Nutritional factors have been recently involved in pathways likely to influence mood and
64 wellbeing. This idea is supported by a growing number of data indicating the protective effects of
65 nutritional factors, including antioxidants, on mood symptoms, cognitive decline and impaired
66 quality of life in the elderly^(3,4). Recent data suggest that the mechanisms by which micronutrients
67 influence health and quality of life involve immunological processes⁽⁵⁾. Alpha (α)-tocopherol is the
68 most bioavailable form of vitamin E. This natural antioxidant is lipid-soluble, and due to this
69 property, it exerts preferentially its antioxidant activity in lipid-rich membranes, **which concerns**
70 **immune cells**. In terms of immunomodulatory properties, α -tocopherol was shown to exert anti-
71 inflammatory actions, including the modulation of T cells function and prostaglandin-E2 production
72 by macrophages and the reduction pro-inflammatory cytokine synthesis from activated
73 macrophages and monocytes^(5,6). The current recommended dietary intake of vitamin E is 15mg
74 per day of α -tocopherol⁽⁷⁾. However, this standard appears not to be reached in the aged population,
75 a condition that may facilitate the development of immune alterations. Inflammation is a
76 fundamental characteristic of aging. In the aged organism, the chronic, low-grade, activation of the
77 innate immunity is associated with an over-expression of inflammatory factors, including pro-
78 inflammatory cytokines (e.g., tumor-necrosis-factor (TNF)- α , interleukin (IL)-6), to the detriment
79 of anti-inflammatory factors⁽⁸⁾. Not only involved in age-related inflammatory processes and
80 disorders, pro-inflammatory cytokines appear also to play a role in the pathophysiology of mood
81 and cognitive disorders, including depression^(9,10). The alteration of tryptophan (TRP) metabolism
82 through the induction of the enzyme indoleamine-2,3-dioxygenase (IDO) upon chronic immune
83 activation represents a mechanism by which inflammation induces mood symptoms. IDO can be
84 induced in a variety of immune cells, such as monocyte-derived macrophages and microglia, by
85 inflammatory cytokines, including most notably IFN- γ ⁽¹¹⁾. This enzyme catalyzes the rate-limiting
86 step of TRP conversion into kynurenine (KYN) and then quinolinic-acid, thereby reducing the
87 availability of TRP for conversion into serotonin. *In vivo*, the activity of IDO is reflected by the
88 relative concentrations of KYN and TRP, **with increased KYN/TRP ratio indicating increased IDO**

89 **activity**. Interestingly, older age has been associated with increasedIDO activity and TRP
90 degradation, consistent with the notion that immune activation is more prominent/sustained in the
91 elderly^(12,13). Altogether, these data support the hypothesis that vitamin E status may participate in
92 aged-related alterations in health and quality of life, through effects on immune function and
93 inflammatory pathways. The purpose of this study was to assess quality of life (mood and physical
94 components) and to determine its relationship to vitamin E status, inflammation and TRP
95 metabolism in a population of elderly subjects.

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97

98 **Subjects and Methods**

99

100 **Participants**

101 Participants (N=69) were recruited from the Three-City (3C) study, an epidemiological cohort study
102 of 9,294 aged, not institutionalized, persons living in Bordeaux, Dijon and Montpellier recruited
103 since 1999 (PI: A. Alperovitch, INSERM U708). The general methodology of the 3C study was
104 published elsewhere⁽¹⁴⁾. Participants in the present study were drawn from the Bordeaux site at 7-
105 year follow up. **Subjects with known or acute signs of inflammatory disease, with dementia or**
106 **taking statins or medications likely to influence immune parameters were excluded. This study was**
107 **conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures**
108 **involving human subjects were approved by the Consultative Committee for the protection of**
109 **Persons in Biomedical Research of the Kremlin-Bicêtre University Hospital (Paris). Written**
110 **informed consent was obtained from all subjects.**

111

112 **Assessment of Quality of Life**

113 Quality of life was assessed using the medical outcomes study (MOS) 36-item short-form
114 health survey (SF-36)⁽¹⁵⁾, a well validated self-report questionnaire which assesses the physical and
115 mental components of quality of life through eight health concepts: physical functioning, physical
116 role functioning, bodily pain, general health, vitality, social functioning, emotional role functioning
117 and mental health. According to standard procedures, two summary scores ranging from 0 to 100
118 (worst to best health) were calculated corresponding respectively to physical health and mental
119 health. These scores were weighted, norm-based and expressed as t-scores with mean=50 (SD=10).

120

121 **Biological Measurements**

122 Fasting blood samples were collected between 8.00am and 9.30 am the same day as the
123 assessment of quality of life. Plasma were stored at -80°C until thawed for the biological assays.

124 **Vitamin E status** – Plasma vitamin E concentrations were measured according to the
125 method of Menke et al ⁽¹⁶⁾. Briefly, after addition of 2,6-di-tert-butyl-p-cresol, vitamin E was
126 extracted from 100µL plasma with hexane and separated by high-performance-liquid-
127 chromatography.

128 **Inflammatory markers** -Assays included the measurement of C-reactive protein (CRP) and
129 the pro-inflammatory cytokine, IL-6. **These markers were selected on the basis of previous reports**
130 **indicating their involvement in neuropsychiatric symptoms in aged populations or with metabolic**
131 **disorders** ^(17, 18). Plasma concentrations of IL-6 were assayed by quantitative enzyme-linked-
132 immunosorbent-assay (ELISA) techniques based on appropriate and validated sets of monoclonal
133 antibodies (R&D Systems). CRP was measured by enzyme-immunoassay (EIA, Chemicon,
134 Millipore, France). Inter- and intra-assay variability is reliably <10%.

135 **TRP catabolism** - Free TRP and KYN plasma concentrations were determined by high-
136 performance-liquid-chromatography, as described elsewhere ⁽¹⁹⁾.

137

138 **Statistical Analysis**

139 Relationship between vitamin E status, inflammatory markers and TRP levels was estimated
140 using the Bravais-Pearson (*R*) coefficient for continuous variables. Separate multivariate linear
141 regression analyses entering biological parameters in separate models adjusting for age and gender
142 were used to assess the association of vitamin E, inflammatory markers and TRP metabolism with
143 the SF-36 physical and mental health summary scores. Finally, dichotomous analyses were
144 performed stratifying participants into distinct subgroups on the basis of their mental and physical
145 health status (poor versus good), as assessed by the SF-36. Good mental and physical health statuses
146 corresponded respectively to a summary mental health score and a summary physical health score
147 above the median of the study population (respectively ≥ 73 and ≥ 67). Analyses of variance with age
148 as covariate (ANCOVA) were performed to compare biological parameters across subgroups. Three
149 participants had a missing value for one question of the SF-36. Accordingly, the missing value was
150 replaced using the algorithm described by the authors ⁽¹⁵⁾. All probabilities were two-tailed, with the
151 level of significance set at $p < 0.05$.

152

153

154 **Results**

155

156 Sixty-nine elderly subjects (46 women, 23 men) participated in the study. The mean age **and**
157 **body mass index (BMI)** of participants were respectively 78.9 years (SD= 4.9) and **27.7 kg/m²**
158 **(SD= 4.3)**. The mean physical health and mental health summary scores were respectively 61.7

159 (SD= 22.6) and 67.4 (SD= 18.9). Overall, there was no significant relationship between gender,
160 BMI and quality of life scores (all $p>0.05$). Age, however, correlated significantly with both the
161 physical and mental components of quality of life (respectively, $R= -.407$, $p<0.001$ and $R= -.363$,
162 $p<0.01$), with greater age corresponding to lower quality of life.

163 As expected, IL-6 levels correlated significantly with CRP levels ($R= .377$, $p<0.01$).
164 Interestingly, IL-6 levels also correlated with vitamin E levels; with higher IL-6 levels
165 corresponding to lower vitamin E concentrations ($R= -.277$, $p<0.01$). CRP concentrations were
166 negatively correlated with levels of TRP ($R= -.270$, $p<0.05$), the latter being also correlated to KYN
167 levels ($R= .443$, $p<0.001$). In addition, there was a trend for a relationship between IL-6 and TRP
168 concentrations ($R= -.209$, $p=0.09$). There was no significant relationship between age, BMI and any
169 of the measured biological parameters. Nevertheless, gender was related to IL-6, TRP, KYN and
170 vitamin E, with women displaying lower levels of IL-6, TRP and KYN and higher levels of vitamin
171 E compared to men (all $p<0.05$). Accordingly, subsequent analyses were performed controlling for
172 the age and gender of participants.

173 Separate multivariate linear regression analyses adjusting for age and gender revealed that
174 IL-6, CRP, TRP and vitamin E were significantly associated with the physical health summary
175 score (respectively $\beta= -.312$, $p=0.007$; $\beta= -.222$, $p=0.047$; $\beta= .299$, $p=0.011$ and $\beta= .317$, $p=0.006$),
176 indicating that the better was physical health status the lower were the concentrations of IL-6 and
177 CRP and the higher were the levels of TRP and vitamin E. Similar analyses associating each
178 biological parameter to the mental health summary score indicated that mental health status was
179 positively associated with TRP levels ($\beta= .282$, $p=0.019$) and with vitamin E ($\beta= .275$, $p=0.022$).

180 Thirty-five participants were found to exhibit poor/low physical health status and 34
181 participants exhibited good physical health status. As shown in **Table 1**, there was no significant
182 difference in terms of gender or BMI between the two subgroups but a significant difference in age,
183 with participants with poor/low physical health being significantly older. When controlling for age,
184 participants with poor/low physical health status were found to exhibit significantly lower levels of
185 vitamin E, higher concentrations of IL-6 and tended to display greater CRP levels compared to
186 participants with high physical health status. Regarding mental health, 35 participants exhibited
187 mental health subscores below the median of the study population, denoting poor/low mental health
188 status. Consistent with differences found for physical health status, participants with poor/low
189 mental health status were found to be older compared to participants with high mental health status.
190 When controlling for age, participants with poor mental health status were found to exhibit
191 significantly lower concentrations of vitamin E and TRP compared to participants with good mental
192 health status.

193

194 **Discussion**

195

196 Results from this study clearly indicate an association between vitamin E status, immune
197 processes and quality of life in the elderly. Participants with greater plasma concentrations of
198 vitamin E (α -tocopherol) exhibited lower plasma levels of inflammation together with better health
199 status, as determined by higher scores of mental and physical quality of life on the SF36
200 questionnaire. This finding is consistent with recent data showing an association between low serum
201 concentrations of α -tocopherol and subsequent decline in physical function in a population-based
202 sample of community-living elders⁽⁴⁾. In our study, plasma concentrations of α -tocopherol
203 correlated with both the mental and physical components of quality of life, suggesting the
204 involvement of vitamin E in multiple dimensions of health and wellbeing.

205 Our findings indicate that regulation of inflammatory processes may represent a primary
206 pathway by which vitamin E influences health and quality of life in the elderly. Due to its
207 antioxidant property, α -tocopherol is able to modulate immune function and regulate inflammatory
208 responses^(5,6). This effect is certainly not negligible in aging where inflammation is prominent and
209 it might thus contribute to improve health and wellbeing in the aged population⁽⁶⁾. Recent data have
210 shown that α -tocopherol can suppress immune-induced TRP degradation in mitogen-stimulated
211 peripheral blood mononuclear cells *in vitro*⁽²⁰⁾. This mechanism could explain the positive
212 association of plasma vitamin E with health and quality of life, given the well-known role of TRP
213 and serotonin pathways in the regulation of mood and neurovegetative functions. In our study,
214 however, α -tocopherol did not significantly correlate with TRP concentrations. Nevertheless,
215 similarly to α -tocopherol, TRP levels were associated with both physical health and mental health,
216 albeit this association was more pronounced in regards to mental health. This data is consistent with
217 the role of TRP metabolism in mood and mental processes and is in line with previous results
218 indicating a significant relationship between immune activation, reduced serum TRP and worse
219 quality of life scores in medically-ill patients⁽²¹⁾. **The dichotomous analysis made to compare**
220 **subgroups in regards to physical and mental health status did not allow us to measure any**
221 **significant difference in KYN levels and in the ratio of KYN/TRP between subgroups.**
222 **Nevertheless, the finding that decreased TRP levels were associated with increased levels of**
223 **inflammatory markers is in favour of the hypothesis of increased TRP degradation upon chronic,**
224 **low-grade, inflammation⁽¹¹⁾.**

225 Lower levels of plasma α -tocopherol in the elderly may either reflect insufficient dietary
226 vitamin E intake^(22,23) or increased formation of reactive oxygen species (ROS) by inflammatory
227 processes, and thus degradation of antioxidants, including vitamin E. These possibilities merit

228 further investigation as they might involve different preventive strategies. In one case, a regular
229 consumption of vitamin E rich compounds, and probably other antioxidants such as carotenoids and
230 polyphenols which contribute to vitamin E regeneration, may prevent age-related alterations in
231 immune function and quality of life. In the other case, supplementation with α -tocopherol may be
232 relevant as this treatment was shown to decrease inflammatory processes and enhance immune
233 function in aged animals ⁽⁶⁾.

234 Altogether these results suggest that vitamin E status may influence quality of life in the
235 elderly and that chronically activated inflammatory pathways may play a role in this relationship.
236 Nevertheless, due to the correlational and cross-sectional aspects of this study, these findings cannot
237 be interpreted in terms of causality. Other limitations to the present study include the limited sample
238 size and the lack of operational control for potential confounders which may be linked to nutritional
239 and immune status as well as to mental health. Despite exclusion of participants with acute
240 inflammatory disease, we cannot rule out an effect of undiagnosed co-morbidity on nutritional and
241 immune status. Finally, because of the absence of specific dietary data documenting on TRP intake
242 at the time of the evaluation, we cannot exclude the possibility that, in addition to inflammatory
243 processes, insufficient dietary intake of TRP-rich compounds may have contributed to decreased
244 TRP concentrations in participants from this study.

245 In conclusion, the present findings document a clear association between vitamin E levels
246 and inflammatory pathways in the elderly and suggest that their interaction may influence quality of
247 life. Insufficient antioxidant intake and/or defences, as assessed by plasma vitamin E, appear to
248 correlate with signs of inflammation and participate in aged-related alterations in health and quality
249 of life.

250

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254 This study was conducted according to the guidelines laid down in the Declaration of Helsinki and
255 all procedures involving human subjects were approved by the Consultative Committee for the
256 protection of Persons in Biomedical Research of the Kremlin-Bicêtre University Hospital (Paris).

257 Written informed consent was obtained from all subjects.

258 Author's contribution: LC was involved in study design, statistical analysis, data interpretation and
259 manuscript writing; AM and VDP performed laboratory measurements of inflammatory markers;

260 NC was responsible for the implementation and measurement of vitamin E; FCG was involved in
261 study design; DF was involved in the measurement of tryptophan and kynurenine; PBG was the

262 local coordinator of the epidemiological study and was involved in study design, data interpretation

263 and manuscript editing; SL was the coordinator of inflammation measurements and was involved in
264 study design, data interpretation and manuscript editing.
265

266 **References**

267

- 268 1. Alexopoulos GS. Depression in the elderly. *Lancet* 2005;365(9475):1961-70.
- 269 2. Hybels CF, Blazer DG. Epidemiology of late-life mental disorders. *Clin Geriatr Med*
270 2003;19(4):663-96.
- 271 3. Deschamps V, Barberger-Gateau P, Peuchant E, Orgogozo JM. Nutritional factors in
272 cerebral aging and dementia: epidemiological arguments for a role of oxidative stress.
273 *Neuroepidemiology* 2001;20(1):7-15.
- 274 4. Bartali B, Frongillo EA, Guralnik JM, et al. Serum micronutrient concentrations and decline
275 in physical function among older persons. *JAMA* 2008;299(3):308-15.
- 276 5. Singh U, Devaraj S, Jialal I. Vitamin E, oxidative stress, and inflammation. *Annu Rev Nutr*
277 2005;25:151-74.
- 278 6. Wu D, Meydani SN. Age-associated changes in immune and inflammatory responses:
279 impact of vitamin E intervention. *J Leukoc Biol* 2008;84(4):900-14.
- 280 7. Institute of Medicine. Dietary reference intakes for vitamin C, vitamin E, selenium, and
281 carotenoids. Washington, DC: National Academy Press; 2000.
- 282 8. Franceschi C, Capri M, Monti D, et al. Inflammaging and anti-inflammaging: a systemic
283 perspective on aging and longevity emerged from studies in humans. *Mech Ageing Dev*
284 2007;128(1):92-105.
- 285 9. Raison CL, Capuron L, Miller AH. Cytokines sing the blues: inflammation and the
286 pathogenesis of depression. *Trends Immunol* 2006;27(1):24-31.
- 287 10. Capuron L, Miller AH. Cytokines and psychopathology: lessons from interferon-alpha. *Biol*
288 *Psychiatry* 2004;56(11):819-24.
- 289 11. Byrne GI, Lehmann LK, Kirschbaum JG, et al. Induction of tryptophan degradation in vitro
290 and in vivo: a gamma-interferon-stimulated activity. *J Interferon Res* 1986;6(4):389-96.
- 291 12. Pertovaara M, Raitala A, Lehtimaki T, et al. Indoleamine 2,3-dioxygenase activity in
292 nonagenarians is markedly increased and predicts mortality. *Mech Ageing Dev* 2006;127(5):497-9.
- 293 13. Frick B, Schroecksnadel K, Neurauter G, et al. Increasing production of homocysteine and
294 neopterin and degradation of tryptophan with older age. *Clin Biochem* 2004;37(8):684-7.
- 295 14. Three-City-Study Group. Vascular factors and risk of dementia: design of the Three-City
296 Study and baseline characteristics of the study population. *Neuroepidemiology* 2003;Sect. 316-25.
- 297 15. Ware JE, Snow KK, Kosinski M, Gandek B. SF-36® Health Survey Manual and
298 Interpretation Guide. Boston, MA: The Health Institute; 1993.

- 299 16. Menke T, Niklowitz P, Adam S, et al. Simultaneous detection of ubiquinol-10, ubiquinone-
300 10, and tocopherols in human plasma microsamples and macrosamples as a marker of oxidative
301 damage in neonates and infants. *Anal Biochem* 2000;282(2):209-17.
- 302 17. Yaffe K, Kanaya A, Lindquist K, et al. The metabolic syndrome, inflammation, and risk of
303 cognitive decline. *Jama* 2004;292(18):2237-42.
- 304 18. Capuron L, Su S, Miller AH, et al. Depressive symptoms and metabolic syndrome: is
305 inflammation the underlying link? *Biol Psychiatry* 2008;64(10):896-900.
- 306 19. Widner B, Werner ER, Schennach H, et al. Simultaneous measurement of serum tryptophan
307 and kynurenine by HPLC. *Clin Chem* 1997;43(12):2424-6.
- 308 20. Winkler C, Schroecksnadel K, Schennach H, Fuchs D. Vitamin C and E suppress mitogen-
309 stimulated peripheral blood mononuclear cells in vitro. *Int Arch Allergy Immunol* 2007;142(2):127-
310 32.
- 311 21. Huang A, Fuchs D, Widner B, et al. Serum tryptophan decrease correlates with immune
312 activation and impaired quality of life in colorectal cancer. *Br J Cancer* 2002;86(11):1691-6.
- 313 22. Gao X, Martin A, Lin H, et al. alpha-Tocopherol intake and plasma concentration of
314 Hispanic and non-Hispanic white elders is associated with dietary intake pattern. *J Nutr*
315 2006;136(10):2574-9.
- 316 23. Panemangalore M, Lee CJ. Evaluation of the indices of retinol and alpha-tocopherol status
317 in free-living elderly. *J Gerontol* 1992;47(3):B98-104.
- 318

Table 1. Vitamin E status, inflammatory markers and TRP catabolism in participants with poor/low mental or physical health versus participants with good mental or physical health

	SF36 – Physical Health		SF36 – Mental Health	
	Poor/low	Good	Poor/low	Good
	(N=35)	(N=34)	(N=35)	(N=34)
Age	80.7 (4.9)	77.1 (4.2) **	80.4 (4.6)	77.4 (4.7) *
Sex (female/male)	24/11	22/12	25/10	21/13
Body mass index (kg/m ²) ^{-b}	26.5 (4.8)	25.1 (3.9)	26.5 (4.9)	25.1 (3.8)
<i>Vitamin E status</i>				
Alpha- tocophérol (µmol/L)	31.3 (5.7)	36.0 (7.9) **	31.7 (6.3)	35.6 (7.7) *
<i>Inflammatory markers</i>				
IL-6 (pg/mL)	5.0 (5.5)	2.8 (1.8) *	4.65 (5.4)	3.16 (2.4)
CRP (mg/L)	5.0 (5.4)	2.9 (3.8) #	4.72 (4.9)	3.15 (4.5)
<i>TRP catabolism</i>				
TRP (µmol/L)	54.9 (10.7)	59.9 (10.9)	53.3 (10.3)	61.5 (10.2) **
KYN (µmol/L)	2.2 (0.7)	2.1 (0.6)	2.1 (0.7)	2.1 (0.5)
KYN/TRP x 1000 (mmol/mol)	40.5 (13.3)	35.1 (8.1)	40.5 (13.6)	35.2 (7.6)

Data are shown as means (SD). IL-6: interleukin-6; CRP: C reactive protein; TRP:

tryptophan; KYN: kynurenine. ** p < 0.01; * p < 0.05; # p = 0.07 (corrected for age)

^{-b} this information was missing for 4 subjects.