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Short Communication

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

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Chronic low-grade inflammation is a characteristic of ageing 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 cohort study participated in the study. Quality of life was assessed using the medical outcomes study thirty-six-item short-form health survey (SF-36). Biological assays included the measurement of plasma vitamin E (α-tocopherol), inflammatory markers, including IL-6 and C-reactive protein, and TRP metabolism. Results showed that participants with poor physical health status, as assessed by the SF-36, exhibited lower circulating concentrations of α-tocopherol together with increased concentrations of inflammatory markers. Similarly, poor mental health scores on the SF-36 were associated with lower concentrations of α-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.

Vitamin E: Ageing: Inflammation: Quality of life

Impaired quality of life, associated with mood and physical symptoms, is frequent in the elderly. Approximately 7–40 % of older individuals report mental dysfunctions, especially in the form of mood and cognitive alterations, and these contribute considerably to their social and occupational dysfunction[1,2]. With the growing elderly population, there is a risk of a recrudescence of age-related behavioural symptoms and reduced wellbeing. Thus, the promotion of healthy lifestyles and the prevention of impaired quality of life in the elderly represent a major public health concern.

Nutritional factors have been recently involved in pathways likely to influence mood and wellbeing. This idea is supported by a growing number of data indicating the protective effects of nutritional factors, including antioxidants, on mood symptoms, cognitive decline and impaired quality of life in the elderly[3,4]. Recent data suggest that the mechanisms by which micronutrients influence health and quality of life involve immunological processes[5]. α-Tocopherol is the most bioavailable form of vitamin E. This natural antioxidant is lipid-soluble, and due to this property, it exerts preferentially its antioxidant activity in lipid-rich membranes, which concerns immune cells. In terms of immunomodulatory properties, α-tocopherol has been shown to exert anti-inflammatory actions, including the modulation of T cell function and PGE2 production by macrophages and the reduction of pro-inflammatory cytokine synthesis from activated macrophages and monocytes[5,6]. The current recommended dietary intake of vitamin E is 15 mg α-tocopherol per d[7]. However, this standard appears not to be reached in the aged population, a condition that may facilitate the development of immune alterations. Inflammation is a fundamental characteristic of ageing. In the aged organism, the chronic, low-grade,

Abbreviations: CRP, C-reactive protein; IDO, indoleamine-2,3-dioxygenase; KYN, kynurenine; SF-36, thirty-six-item short-form health survey; TRP, tryptophan.

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activation of the innate immunity is associated with an over-expression of inflammatory factors, including pro-inflammatory cytokines (for example, TNF-α, IL-6), to the detriment of anti-inflammatory factors[8]. Not only involved in age-related inflammatory processes and disorders, pro-inflammatory cytokines appear also to play a role in the pathophysiology of mood and cognitive disorders, including depression[9,10]. The alteration of tryptophan (TRP) metabolism through the induction of the enzyme indoleamine-2,3-dioxygenase (IDO) upon chronic immune activation represents a mechanism by which inflammation induces mood symptoms. IDO can be induced in a variety of immune cells, such as monocyte-derived macrophages and microglia, by inflammatory cytokines, including most notably interferon-γ[11]. This enzyme catalyses the rate-limiting step of TRP conversion into kynurenine (KYN) and then quinolinic acid, thereby reducing the availability of TRP for conversion into serotonin. *In vivo*, the activity of IDO is reflected by the relative concentrations of KYN and TRP, with an increased KYN:TRP ratio indicating increased IDO activity. Interestingly, older age has been associated with increased IDO activity and TRP degradation, consistent with the notion that immune activation is more prominent/sustained in the elderly[12,13]. Altogether, these data support the hypothesis that vitamin E status may participate in age-related alterations in health and quality of life, through effects on immune function and inflammatory pathways. The purpose of the present study was to assess quality of life (mood and physical components) and to determine its relationship to vitamin E status, inflammation and TRP metabolism in a population of elderly subjects.

Subjects and methods

Participants

Sixty-nine participants were recruited from the Three-City study, an epidemiological cohort study of 9294 aged, not institutionalised, individuals living in Bordeaux, Dijon and Montpellier recruited since 1999. The principal investigator is A. Alpérovitch (INSERM U708, Paris, France). The general methodology of the Three-City study has been published elsewhere[14]. Participants in the present study were drawn from the Bordeaux site at the 7-year follow-up. Subjects with known or acute signs of inflammatory disease, with dementia or taking statins or medications likely to influence immune parameters were excluded. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Consultative Committee for the protection of Persons in Biomedical Research of the Kremlin-Bicêtre University Hospital (Paris). Written informed consent was obtained from all subjects.

Assessment of quality of life

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

Biological measurements

Fasting blood samples were collected between 08.00 and 09.30 hours the same day as the assessment of quality of life. Plasma was stored at −80°C until thawed for the biological assays.

Vitamin E status. Plasma vitamin E concentrations were measured according to the method of Menke *et al.* [16]. Briefly, after addition of 2,6-di-tert-butyl-*p*-cresol, vitamin E was extracted from 100 µl plasma with hexane and separated by HPLC.

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

Tryptophan catabolism. Free TRP and KYN plasma concentrations were determined by HPLC, as described elsewhere[19].

Statistical analysis

The relationship between vitamin E status, inflammatory markers and TRP levels was estimated using the Bravais–Pearson (*R*) coefficient for continuous variables. Separate multivariate linear regression analyses entering biological parameters in separate models adjusting for age and sex were used to assess the association of vitamin E, inflammatory markers and TRP metabolism with the SF-36 physical and mental health summary scores. Finally, dichotomous analyses were performed stratifying participants into distinct subgroups on the basis of their mental and physical health status (poor *v.* good), as assessed by the SF-36. Good mental and physical heath statuses corresponded respectively to a summary mental health score and a summary physical health score above the median of the study population (respectively ≥ 73 and ≥ 67). Analyses of variance with age as covariate (ANCOVA) were performed to compare biological parameters across subgroups. Three participants had a missing value for one question of the SF-36. Accordingly, the missing value was replaced using the algorithm described by the authors[15]. All probabilities were two-tailed, with the level of significance set at $P < 0{\cdot}05$.

Results

Sixty-nine elderly subjects (forty-six women, twenty-three men) participated in the study. The mean age and BMI of

participants were respectively 78·9 (SD 4·9) years and 27·7 (SD 4·3) kg/m^2. The mean physical health and mental health summary scores were respectively 61·7 (SD 22·6) and 67·4 (SD 18·9). Overall, there was no significant relationship between sex, BMI and quality of life scores (all $P>0·05$). Age, however, correlated significantly with both the physical and mental components of quality of life (respectively, R −0·407, $P<0·001$ and R −0·363, $P<0·01$), with greater age corresponding to lower quality of life.

As expected, IL-6 levels correlated significantly with CRP levels (R 0·377; $P<0·01$). Interestingly, IL-6 levels also correlated with vitamin E levels, with higher IL-6 levels corresponding to lower vitamin E concentrations (R −0·277; $P<0·01$). CRP concentrations were negatively correlated with levels of TRP (R −0·270; $P<0·05$), the latter being also correlated to KYN levels (R 0·443; $P<0·001$). In addition, there was a trend for a relationship between IL-6 and TRP concentrations (R −0·209; $P=0·09$). There was no significant relationship between age, BMI and any of the measured biological parameters. Nevertheless, sex was related to IL-6, TRP, KYN and vitamin E, with women displaying lower levels of IL-6, TRP and KYN and higher levels of vitamin E compared with men (all $P<0·05$). Accordingly, subsequent analyses were performed controlling for the age and sex of participants.

Separate multivariate linear regression analyses adjusting for age and sex revealed that IL-6, CRP, TRP and vitamin E were significantly associated with the physical health summary score (respectively β −0·312, $P=0·007$; β −0·222, $P=0·047$; β 0·299, $P=0·011$; β 0·317, $P=0·006$), indicating that the better the physical health status, the lower were the concentrations of IL-6 and CRP and the higher were the levels of TRP and vitamin E. Similar analyses associating each biological parameter to the mental health summary score indicated that mental health status was positively associated with TRP levels (β 0·282; $P=0·019$) and with vitamin E (β 0·275; $P=0·022$).

Thirty-five participants were found to exhibit poor/low physical health status and thirty-four participants exhibited good physical health status. As shown in Table 1, there was no significant difference in terms of sex or BMI between the two subgroups but a significant difference in age, with participants with poor/low physical health being significantly older. When controlling for age, participants with poor/low physical health status were found to exhibit significantly lower levels of vitamin E, higher concentrations of IL-6 and tended to display greater CRP levels compared with participants with high physical health status. Regarding mental health, thirty-five participants exhibited mental health subscores below the median of the study population, denoting poor/low mental health status. Consistent with differences found for physical health status, participants with poor/low mental health status were found to be older compared with participants with high mental health status. When controlling for age, participants with poor mental health status were found to exhibit significantly lower concentrations of vitamin E and TRP compared with participants with good mental health status.

Discussion

Results from the present study clearly indicate an association between vitamin E status, immune processes and quality of life in the elderly. Participants with greater plasma concentrations of vitamin E (α-tocopherol) exhibited lower plasma levels of inflammation together with better health status, as determined by higher scores of mental and physical quality of life on the SF-36 questionnaire. This finding is consistent with recent data showing an association between low serum concentrations of α-tocopherol and subsequent decline in physical function in a population-based sample of

Table 1. Vitamin E status, inflammatory markers and tryptophan (TRP) catabolism in participants with poor/low mental or physical health *v.* participants with good mental or physical health

(Mean values and standard deviations)

	SF-36 – physical health				SF-36 – mental health			
	Poor/low (*n* 35)		Good (*n* 34)		Poor/low (*n* 35)		Good (*n* 34)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	80·7	4·9	77·1**	4·2	80·4	4·6	77·4*	4·7
Sex (*n*)								
Female	24		22		25		21	
Male	11		12		10		13	
BMI (kg/m^2)‡	26·5	4·8	25·1	3·9	26·5	4·9	25·1	3·8
Vitamin E status								
α-Tocopherol (μmol/l)	31·3	5·7	36·0**	7·9	31·7	6·3	35·6*	7·7
Inflammatory markers								
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
TRP catabolism								
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 × 1000 (mmol/mol)	40·5	13·3	35·1	8·1	40·5	13·6	35·2	7·6

SF-36, thirty-six-item short-form health survey[15]; CRP, C-reactive protein; KYN, kynurenine.
Mean value was significantly different from that of the poor/low group: * $P<0·05$, ** $P<0·01$ (corrected for age).
† Mean value was marginally significantly different from that of the poor/low group ($P=0·07$) (corrected for age).
‡ This information was missing for four subjects.

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community-living elders[4]. In the present study, plasma concentrations of α-tocopherol correlated with both the mental and physical components of quality of life, suggesting the involvement of vitamin E in multiple dimensions of health and wellbeing.

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

Lower levels of plasma α-tocopherol in the elderly may either reflect insufficient dietary vitamin E intake[22,23] or increased formation of reactive oxygen species by inflammatory processes, and thus degradation of antioxidants, including vitamin E. These possibilities merit further investigation as they might involve different preventive strategies. On one hand, a regular consumption of vitamin E-rich compounds, and probably other antioxidants such as carotenoids and polyphenols which contribute to vitamin E regeneration, may prevent age-related alterations in immune function and quality of life. On the other hand, supplementation with α-tocopherol may be relevant, as this treatment has been shown to decrease inflammatory processes and enhance immune function in aged animals[6].

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

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

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The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Consultative Committee for the protection of Persons in Biomedical Research of the Kremlin-Bicêtre University Hospital (Paris). Written informed consent was obtained from all subjects.

L. C. was involved in study design, statistical analysis, data interpretation and manuscript writing; A. M. and V. D. S.-P. performed laboratory measurements of inflammatory markers; N. C. was responsible for the implementation and measurement of vitamin E; F. C.-G. was involved in study design; D. F. was involved in the measurement of TRP and KYN; P. B.-G. was the local coordinator of the epidemiological study and was involved in study design, data interpretation and manuscript editing; S. L. was the coordinator of inflammation measurements and was involved in study design, data interpretation and manuscript editing.

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References

1. Alexopoulos GS (2005) Depression in the elderly. *Lancet* **365**, 1961–1970.
2. Hybels CF & Blazer DG (2003) Epidemiology of late-life mental disorders. *Clin Geriatr Med* **19**, 663–696.
3. Deschamps V, Barberger-Gateau P, Peuchant E, *et al.* (2001) Nutritional factors in cerebral aging and dementia: epidemiological arguments for a role of oxidative stress. *Neuroepidemiology* **20**, 7–15.
4. Bartali B, Frongillo EA, Guralnik JM, *et al.* (2008) Serum micronutrient concentrations and decline in physical function among older persons. *JAMA* **299**, 308–315.
5. Singh U, Devaraj S & Jialal I (2005) Vitamin E, oxidative stress, and inflammation. *Annu Rev Nutr* **25**, 151–174.
6. Wu D & Meydani SN (2008) Age-associated changes in immune and inflammatory responses: impact of vitamin E intervention. *J Leukoc Biol* **84**, 900–914.

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7. Institute of Medicine (2000) *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*. Washington, DC: National Academy Press.
8. Franceschi C, Capri M, Monti D, *et al.* (2007) Inflammaging and anti-inflammaging: a systemic perspective on aging and longevity emerged from studies in humans. *Mech Ageing Dev* **128**, 92–105.
9. Raison CL, Capuron L & Miller AH (2006) Cytokines sing the blues: inflammation and the pathogenesis of depression. *Trends Immunol* **27**, 24–31.
10. Capuron L & Miller AH (2004) Cytokines and psychopathology: lessons from interferon-α. *Biol Psychiatry* **56**, 819–824.
11. Byrne GI, Lehmann LK, Kirschbaum JG, *et al.* (1986) Induction of tryptophan degradation *in vitro* and *in vivo*: a γ-interferon-stimulated activity. *J Interferon Res* **6**, 389–396.
12. Pertovaara M, Raitala A, Lehtimaki T, *et al.* (2006) Indoleamine 2,3-dioxygenase activity in nonagenarians is markedly increased and predicts mortality. *Mech Ageing Dev* **127**, 497–499.
13. Frick B, Schroecksnadel K, Neurauter G, *et al.* (2004) Increasing production of homocysteine and neopterin and degradation of tryptophan with older age. *Clin Biochem* **37**, 684–687.
14. 3C Study Group (2003) Vascular factors and risk of dementia: design of the Three-City Study and baseline characteristics of the study population. *Neuroepidemiology* **22**, 316–325.
15. Ware JE, Snow KK, Kosinski M, *et al.* (1993) *SF-36® Health Survey Manual and Interpretation Guide*. Boston, MA: The Health Institute.
16. Menke T, Niklowitz P, Adam S, *et al.* (2000) Simultaneous detection of ubiquinol-10, ubiquinone-10, and tocopherols in human plasma microsamples and macrosamples as a marker of oxidative damage in neonates and infants. *Anal Biochem* **282**, 209–217.
17. Yaffe K, Kanaya A, Lindquist K, *et al.* (2004) The metabolic syndrome, inflammation, and risk of cognitive decline. *JAMA* **292**, 2237–2242.
18. Capuron L, Su S, Miller AH, *et al.* (2008) Depressive symptoms and metabolic syndrome: is inflammation the underlying link? *Biol Psychiatry* **64**, 896–900.
19. Widner B, Werner ER, Schennach H, *et al.* (1997) Simultaneous measurement of serum tryptophan and kynurenine by HPLC. *Clin Chem* **43**, 2424–2426.
20. Winkler C, Schroecksnadel K, Schennach H, *et al.* (2007) Vitamin C and E suppress mitogen-stimulated peripheral blood mononuclear cells *in vitro*. *Int Arch Allergy Immunol* **142**, 127–132.
21. Huang A, Fuchs D, Widner B, *et al.* (2002) Serum tryptophan decrease correlates with immune activation and impaired quality of life in colorectal cancer. *Br J Cancer* **86**, 1691–1696.
22. Gao X, Martin A, Lin H, *et al.* (2006) α-Tocopherol intake and plasma concentration of Hispanic and non-Hispanic white elders is associated with dietary intake pattern. *J Nutr* **136**, 2574–2579.
23. Panemangalore M & Lee CJ (1992) Evaluation of the indices of retinol and α-tocopherol status in free-living elderly. *J Gerontol* **47**, B98–B104.

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