Published in final edited form as:

Psychol Aging. 2012 December ; 27(4): 892–902. doi:10.1037/a0029093.

Psychosocial resources, aging, and natural killer cell terminal maturity

Suzanne C. Segerstrom,

Department of Psychology; University of Kentucky

Ahmad Al-Attar, and

Department of Pathology and Laboratory Medicine; University of Kentucky

Charles T. Lutz

Department of Microbiology, Immunology and Molecular Genetics and Department of Pathology and Laboratory Medicine. University of Kentucky

Abstract

Psychosocial factors may influence aspects of immunological aging. The present study tested the hypothesis that psychosocial resources correlate with the expression of the cell surface marker CD57 on natural killer (NK) immune cells. CD57 is a marker of terminal maturation and senescence in this cell subset. The study further tested the relative contribution of specific resources in the social, psychological, financial, and status-skill domains, given the potential differential value of different resources for younger and older adults, and the contribution of relative vs. absolute resources. Younger (N=38) and older (N=34) women completed measures of relative and absolute resources and had blood drawn. Examined both between groups and within the older women, older age and fewer total relative resources were associated with more CD57 expression on NK cells. One SD in resources was the equivalent of 5 years of aging among the older women. Among the specific resource types, a preponderance of financial resources, both relative and absolute, was associated with less CD57 expression on NK cells, and these relationships did not significantly vary between younger and older women. There was no evidence that depressive symptoms mediated the effects of resources on CD57 expression on NK cells. These findings provide support for the hypothesis that the sense that one has substantial resources, particular with regard to finances and possessions, may retard age-associated aspects of the microenvironment in which NK cells develop and mature, independent of effects on distress, and this process may begin in younger adulthood.

Keywords

Natural killer cell; CD57; senescence; aging; resources; social; financial; psychological; status

Immunological aging is thought to contribute to health risks, including increased vulnerability to infectious disease and cancer. For example, immune cells generally have a limited capability to divide, replicate, and proliferate (i.e., the Hayflick Limit; Effros & Pawelec, 1997). Once they reach this limit, these cells may maintain their individual capability (e.g., to kill an infected cell), but they cannot effectively create new, expanded sets of daughter cells that may be required to respond to challenge such as infection. The age-related accumulation of cells that have reached replicative senescence may also inhibit

the generation of new cells and promote a low-grade inflammatory environment, further increasing risk for age-related diseases such as atherosclerosis, Alzheimer's disease, and frailty (Effros, in press; Ershler & Keller, 2000; Pawelec et al., 2005; Ross, 1999). Cells that have reached terminal maturity or replicative senescence can be identified by the cell surface proteins that they either begin to express or fail to express.

The present investigation examines the correlation between psychosocial resources and expression of the cell surface marker CD57 on natural killer (NK) cells in younger and older women. NK cells are part of the immune system. Their role is to kill virally infected cells and, potentially, tumor cells, and to secrete proteins (cytokines) that communicate with and activate other immune cells. NK cells can kill multiple targets and do so quickly, and as such they are important to the control of the early stages of disease, before other parts of the immune system are ready to respond (Vivier et al., 2011). When stimulated by targets, cytokines, or both, they divide and proliferate, creating an expanded population of NK cells to fight the disease.

NK cells have relatively short life spans of approximately 2 weeks, during the end of which they begin to express the cell surface marker CD57. Compared with CD57[−] NK cells, CD57⁺ cells proliferate less constitutively and much less in response to various stimulatory signals, although individual cells continue to be able to kill their targets (Björkström et al., 2010; Hayhoe, Henson, Akbar, & Palmer, 2010; Lopez-Verges et al., 2010; Lutz et al., 2011). These data suggest that CD57⁺ NK cells have reached terminal maturation and replicative senescence. Compared with young adults, healthy older adults typically have as many or more NK cells in peripheral blood, which has led to the proposition that NK cells play an important role in immunocompetence in older adulthood (Sansoni et al., 1993; Solana, Pawelec, & Tarazona, 2006). In one study, healthy younger and older women also did not differ in NK cell turnover or lifespan (Lutz et al., 2011). Older adults nonetheless have a higher *proportion* of CD57⁺ NK cells than younger adults (Lutz et al., 2011; Sansoni et al., 1993). These data indicate that NK cells in older adults have an accelerated progression to the CD57⁺ state and spend a greater proportion of their lifespan in that state, suggesting more replicative senescence and less ability to meet immune challenges in older age.

A few studies have found relationships between psychosocial factors and immune cell aging, mainly in middle- or late middle-age samples. Caregiving stress and work burnout were associated with shorter telomeres on immune cells in peripheral blood, which can indicate replicative senescence (Damjanovic et al., 2007; Epel et al., 2004; Wikgren et al., 2012), and with higher percentages of NK cells expressing the CD57 cell surface marker (Nakamura, Nagase, Yoshida, & Ogino, 1999). In contrast, aerobic fitness was negatively correlated with the percentage of terminally mature immune cells (in this case, T cells; Spielmann et al., 2011). These studies indicate that the process of immunological aging in general and replicative senescence in particular may be affected by psychosocial and behavioral factors. However, they provide minimal insight into the role of aging in this process, as only one study examined older adults specifically (Damjanovic et al., 2007), and age comparisons were restricted to reports that older participants had a higher percentage of senescent cells than younger participants.

Resources, health, and immunological aging

Resources have proven to be important and robust predictors of lower physical morbidity and mortality. There are many potential resource domains, but financial, status, social, and psychological resources have strong links to health and longevity. Such resources include, for example, positive beliefs about the self and the future (Levy, Slade, Kunkel, & Kasl,

2002), socioeconomic status (SES; Gallo, Bogart, Vranceanu, & Matthews, 2005; Marmot et al., 1991; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007), number of social relationships (Holt-Lunstad, Smith, & Layton, 2010; House, Landis, & Umberson, 1988), and involvement in religious services (Powell, Shahabi, & Thoresen, 2003). Psychosocial resources are therefore a good place to begin to look for predictors of immunological health and aging.

Resource models of psychosocial resilience and vulnerability are similar to models of stress insofar as loss or scarcity in resources is thought to contribute to stress. However, they are more inclusive than most such models (Hobfoll, 1989; Segerstrom, 2010). Resources are thought not only to provide a buffer against the occurrence and impact of stressful events but also enhance the potential for positive events (e.g., having more friends means more potential social support under stress but also more positive social events such as parties). Therefore, resources may both mitigate against circumstances (e.g., stress, depression) that increase risk for poor immune outcomes (Segerstrom & Miller, 2004) and promote circumstances (e.g., positive affect and events) that may decrease risk (Steptoe, Dockray, & Wardle, 2009). Our hypothesis was that women with lower psychosocial resources would have a higher proportion of NK cells expressing CD57 relative to their peers with higher resources, because lower resources could contribute to acceleration of NK cells toward terminal maturation and replicative senescence.

Women reported on the degree of resources they perceived themselves to have relative to other women their age. In addition to measuring resources net of age, this method captured *subjective* or *relative* resources. Evidence, primarily in the domain of SES, suggests that relative resources capture a source of variance related to but distinct from absolute resources. In large-scale studies of middle-aged and older adults, both absolute and relative resources predicted change in self-reported health and likelihood of metabolic syndrome (comprising hypertension, hyperglycemia, and hyperlipidemia) (Demakakos, Nazroo, Breezer, & Marmot, 2008; Manuck, Phillips, Gianaros, Flory, & Muldoon, 2010; Singh-Manoux, Marmot, & Adler, 2005). After experimental infection with a cold virus, younger and middle-aged adults with low relative SES were more than three times as likely to develop a clinical cold after controlling for income and education (Cohen et al., 2008). Relative resources are thought to add predictive power because they capture how people *feel* about their resources, which can in turn affect emotional and stress responses and therefore health.

Although resources in multiple domains are likely to be health-promoting across the lifespan, different resource domains may vary in their importance to people at different life stages (Carstensen, Isaacowitz, & Charles, 1999). Specifically, when there is abundant time remaining in life, people are more likely to adopt goals related to knowledge, skill, or status that can be “cashed in” later. However, when there is less time remaining in life, as in older age, people are more likely to adopt goals related to present, hedonic enjoyment (Lang & Carstensen, 2002; Ridieger, Schmiedek, Wagner, & Lindenberger, 2009). This shift in goals also shows up in preferred social contacts: younger adults are more likely to value contact with distant but knowledgeable others, whereas older adults are more likely to value contact with emotionally close others (e.g., Carstensen, 1992; Fredrickson & Carstensen, 1990; Lang & Carstensen, 2002). Resources are more likely to contribute to well-being when they are congruent with values and goals (Diener & Fujita, 1995). Therefore, older adults may benefit immunologically more than younger adults from having resources that are more closely associated with hedonic value (i.e., social and psychological resources) relative to resources that are not (i.e., status and financial resources).

The present study

The present study tested the relationship of relative resources to NK cell terminal maturation and replicative senescence in younger and older women. We hypothesized that we would observe a larger percentage of CD57+ NK cells both in older compared with younger women and with increasing age within the older women, and that higher relative resources would be associated with a smaller percentage of CD57+ NK cells. In addition, older women may be more vulnerable to immunological effects of psychosocial adversity (Segerstrom & Miller, 2004). However, it is also possible that higher relative resources are associated with a slower rate of immunological aging across the lifespan (Epel, 2009; Graham et al., 2006). Previous studies have found relationships between psychosocial factors and markers of replicative senescence in middle age, and it is possible that these relationships may extend into younger adulthood. Therefore, the hypothesis that age and relative resources interact was considered exploratory.

Based on the possibility that different classes of resources are differentially important for younger and older adults, we addressed the hypothesis that older adults would benefit more from relative resources in the social and personal domains and younger adults, in the financial and status domains. The relative contribution of the different domains to the percentage of CD57+ NK cells was therefore tested above and beyond their shared contribution: that is, do higher resources in one particular domain over others predict a lower percentage of CD57+ NK cells?

Finally, we tested the degree to which absolute and relative resources made unique contributions. Based on previous work examining the relationship of absolute and relative SES to other measures of health, we hypothesized that relative resources would predict the percentage of CD57+ NK cells above and beyond absolute resources. By entering absolute and relative resources in the same model, we tested whether residual variance in the percentage of CD57+ NK cells not accounted for by one source (absolute or relative resources) could be accounted for by the other source.

Method

Participants

Participants consisted of 34 older women (M age = 81.5, range = 74 – 97) and 38 younger women (M age = 26.6, range = 21 – 31). Older and younger women did not significantly differ in percent married (24% in both groups; unmarried participants were primarily widowed in the older group [56%] and never married in the younger group [71%]), racial distribution (79% vs. 74% Caucasian), BMI (M = 24.9 vs. 23.8), or household income. Consistent with expected cohort differences, older women had significantly less education. Older women reported significantly higher relative financial resources and relative social resources than younger women, but the two groups did not differ on relative psychological or relative status-skill resources (see Table 1).

All participants met strict criteria in a screening telephone call designed to ensure good general health. Exclusion criteria included history of immunologic illness or cancer, use of immunomodulatory drugs, regular consumption of ≥ 28 grams ethanol per day, morbid obesity (BMI > 40), and depression (score > 16 on the Center for Epidemiologic Studies – Depression (CES-D) scale). Older women were recruited from a volunteer subject pool generated by a county-wide mailing to all adults aged 60 and older on the voter registration roll and maintained by the university's Center on Aging. Participants were mailed a letter describing the study and subsequently contacted by phone to ascertain interest in the study and to be screened. Younger women were recruited by advertisement in hospital and

academic buildings and on a research web site and were also screened by phone on contact with the study. Of the 45 older women contacted and screened, 76% were recruited. Of those not recruited, the reasons were cancer history ($N = 6$), use of corticosteroids ($N = 3$), and use of alcohol ($N = 2$). Of the 41 younger women contacted and screened, 93% were recruited. Of those not recruited, the reasons were use of corticosteroids ($N = 1$), use of alcohol ($N = 1$), and possible pregnancy ($N = 1$).

Measures and Procedure

All procedures were performed with the approval of the University of Kentucky Institutional Review Board.

Relative resources—The measure of relative psychosocial resources was adapted from the Conservation of Resources Evaluation (Hobfoll & Lilly, 1993). The scale asked women to report the degree of each of 74 resources they believed themselves to have relative to the average person of their age, using a 7-point scale (1 = much less, 7 = much more). Social resources were captured with 9 items (see Appendix; $\alpha = .85$). Within the social domain, there are multiple important dimensions of social relationships, including both the number of such relationships and their quality (e.g., warmth). A broad assessment of social resources therefore includes good relationships, intimacy, and companionship across a number of possible relationships, capturing both the quantity and quality of social resources. Financial resources and possessions were captured with 18 items (see Appendix; $\alpha = .94$). Whereas income is a good measure of financial resources for working adults, it is a poorer measure of financial resources for older adults, for whom retirement savings, housing, and other assets may be better markers (Banks, Karlsen, & Oldfield, 2003). Therefore, a broader measure is likely to capture relevant resources across age groups. Status and skill were captured with 6 items (see Appendix; $\alpha = .88$), and psychological resources with 19 items (see Appendix; $\alpha = .94$). Within the psychological domain, studies commonly employ composite measures of, for example, optimism, mastery or control, and self-esteem (Taylor & Stanton, 2007), recognizing that these measures are closely related to each other and that their joint effects may be of greater importance than specific effects. The remaining, unused items had low response rates because they applied only to a subset of the sample: these items referred to marriage, work, and children.

Absolute resources—Measures included household income, attendance at religious services, dispositional optimism, and education level. Income was reported in \$10,000 increments from < \$10,000 to > \$90,000. Attendance at religious services was reported as 0 = never ($N = 15$); 1 = once or twice a year ($N = 11$); 2 = every few months ($N = 10$); 3 = once or twice a month ($N = 7$); 4 = weekly ($N = 19$); 5 = twice or more weekly ($N = 9$). Dispositional optimism was measured with the Life Orientation Test – Revised (LOT-R; Scheier, Carver, & Bridges, 1994). The LOT-R asks about generalized expectations for the future without reference to other people and is largely independent of relative expectations (i.e., whether one is more or less likely than others to experience positive or negative events in the one's future; Geers, 2000; Lipkus, Martz, Panter, Drigotas, & Feaganes, 1993). Education level was reported as 1 = some school, but not a high school degree ($N = 0$); 2 = completed high school degree ($N = 10$); 3 = some college, but not a degree ($N = 19$); 4 = completed college degree ($N = 12$); 5 = some graduate school, but not a degree ($N = 13$); 6 = completed graduate or professional degree ($N = 18$).

Measures were completed on the same day as blood draw, identified only by a subject ID number, and returned to study personnel.

Depressive symptoms—Depressive symptoms were measured using the CES-D (Radloff, 1977). This scale captures depressive symptomatology, particularly the affective component. This measure was completed at the screening interview, which took place a mean of 23 days before the blood draw ($SD = 18$). Two older women refused the CES-D but reported normal mood. Values for these two women were replaced with the group-specific mean (3.4) for analysis involving this scale, but the results without these two women were substantively unchanged. Because the sample was selected for low depression, this measure should be interpreted as a reflection of subclinical depressive symptoms rather than depression *per se*. However, it should be noted that no potential participants were excluded based on CES-D score, and so this sample is not unrepresentative of prospective study volunteers as a whole in terms of depressive symptoms.

Immune parameters—Blood was collected by venipuncture, the immune cell fraction was enriched by centrifugation, and the sample was analyzed fresh. Cells were stained with monoclonal antibody to cell surface markers including CD3 (T cell receptor), CD16 (Fc receptor), CD56 (NK lineage marker), and CD57. Flow cytometry was used to determine the percentage of cells within NK cell subsets. The subset of interest was CD3[−] (to exclude T cells), CD56^{dim}, and CD57⁺. The percentage of NK cells that are CD56^{dim} rather than CD56^{bright} is higher in older adults (Hayhoe et al., 2010; Lutz et al., 2011). However, CD56^{dim} cells are better characterized as mature rather than senescent; in the absence of CD57, they proliferate and have high cytotoxic and cytokine production capacities. We focused on this subset because the correlates of CD57 expression have been best established on CD56^{dim} cells (Björkström et al., 2010; Lopez-Verges et al., 2010; Lutz et al., 2011), and the expression of CD57 on CD56^{bright} cells is low and its meaning is controversial (Hayhoe et al., 2010; Lopez-Verges et al., 2010).

Participants were asked if they were feeling well in a call the day before the blood draw and again on the day of the blood draw. Anyone who reported not feeling well had the blood draw deferred to a later day. All participants had vital signs taken, and none had elevated temperatures or other indications of acute infection at the time of blood draw. Blood was drawn between 7:45 and 8:30 am to control for potential circadian variation.

Data analysis—Data were analyzed using hierarchical linear regression models. All linear predictors were mean centered to aid in estimation of interactions. The first research question had to do with the effects of age group (younger vs. older women) or age (among the older women) and total relative resources. Because the relative resource domains were all positively correlated with each other (see Table 1), the effect of total relative resources, the sum of these four standardized scores ($\alpha = .88$), was tested to assess their shared contribution. Therefore, in the first set of models, age was treated as a categorical predictor (younger vs. older) and entered at the first step of the regression. The second step entered the main effect of relative resources, yielding the effect of resources net of age group, and the third step entered the interaction between age group and relative resources. In the second set of models, age in years was treated as a continuous predictor within the older women and entered at the first step. The second step entered the main effect of resources, yielding the effect of resources net of age, and the third step entered the interaction between age and relative resources.

The second research question had to do with the contributions of the individual resource domains. In these models, relative resources were entered individually rather than as a composite into the regression models described above. This secondary analysis had no effect on their shared ability to predict (i.e., R^2 remained the same), but the individual beta weights in this model then reflected the contribution of each resource domain above and beyond shared variance with the other domains.

Finally, the ability of absolute resources to predict CD57 expression on NK cells above and beyond relative resources was tested by entering absolute resources in a further step in the regression. As noted above, this step tests whether residual variance in the immune measure after its prediction by relative resources can be predicted by absolute resources (and vice versa). Some older women did not respond to the household income measure ($N = 9$). Therefore, correlations and regressions involving this measure were performed using pooled values derived from multiple imputation in SPSS (Version 20; Armonk, NY) with 10 imputations and all other resource measures as the basis for imputation. Note that women who responded to the income question were not significantly different from those who did on any other resource measure or depressive symptoms (all $p > .20$).

Results

Relative and absolute resources: Validity evidence

Table 1 provides convergent and divergent validity correlations among the relative resource measures (social, financial, psychological, and status-skill) and absolute resources (religious attendance, household income, dispositional optimism, and years of education). Relative resources were somewhat more highly correlated with each other in older than in younger women, but showed substantial coherence in both groups. The generally positive correlations among relative resources were expected given previous evidence for positive relationships among resources (e.g., Segerstrom, 2007). The correlations among absolute resources were also positive but of much lower magnitude. In both younger and older women, the convergent correlations were higher than the divergent correlations. There was one exception, which was status-skill resources, which were not correlated with years of education. This may be a function of the generally high educational level of the sample. In sum, relative and absolute resources can be considered to capture related but distinct domains.

Relative resources and NK terminal maturity

The first set of analyses assessed the relationship of total relative resources to CD57 expression on NK cells in younger and older groups of women (see Table 2, Model 1). There were significant effects of both age group and total resources on the percentage of NK cells that were CD57+. Older women had higher percentages of CD56^{dim}CD57+ NK cells than younger women. However, women with more total resources had lower percentages of CD56^{dim}CD57+ NK cells. Therefore, total resources had the inverse effect of age: The more resources an older woman had, the more she began to resemble a younger woman in terms of her percentage of CD56^{dim}CD57+ NK cells. Figure 1 portrays the slopes for younger and older women from high (+1 SD) to low (−1 SD) resources, demonstrating the relative magnitude of the age group and resource effects. There was not a significant interaction between age group and total resources.

The second set of analyses assessed the roles of age and total resources among older women (see Table 2, Model 2). Even within the restricted age range and smaller sample size of the older women, older age tended to correlate with higher percentage of CD56^{dim}CD57+ cells. In addition, higher total resources significantly predicted a lower percentage of CD56^{dim}CD57+ cells. The magnitude of this effect can be compared with that of aging: Each additional year of age was associated with an increase of 1.5 in the percentage of CD56^{dim}CD57+ cells; each additional standard deviation of total resources was associated with a decrease of 8.6 in the same percentage – the equivalent of 5.7 years of aging. There was not a significant interaction between age and total resources within the older women.

Finally, regression models tested the effects of having higher relative resources in a specific domain above and beyond that domain's shared variance with the other domains. In these analyses, only higher financial resources predicted lower percentages of CD56^{dim}CD57+ NK cells above and beyond its shared effects with all relative resources. This was true in the total sample (Table 3, Model 1), as well as among older women only (Table 4, Model 1). Domain-specific relative resources did not interact with age group or age (Table 3 and Table 4, Model 2).

Relative resources, absolute resources, and NK terminal maturity

The final set of models tested whether there was specific variance in relative or absolute resources that predicted NK terminal maturity above and beyond their shared variance. In the total sample (Table 3, Model 3), relative financial resources was no longer a significant predictor (with the unstandardized beta weight falling from -9.4 to -6.5) with its highest zero-order correlate, household income, in the model. In contrast, higher household income above and beyond relative financial resources was a significant predictor of a lower percentage of CD56^{dim}CD57+ NK cells. Therefore, after accounting for that amount of the percentage of CD56^{dim}CD57+ NK cells that was predicted by relative financial resources (Table 3, Model 1), the residual amount could be predicted by household income (Table 3, Model 3). This was not true, however, among the older women only. Neither relative nor absolute resources (financial or otherwise) significantly predicted the percentage of CD56^{dim}CD57+ NK cells above and beyond their shared variance with other resources (Table 4, Model 3).

There was also an unexpected effect of dispositional optimism above and beyond psychological resources in the total sample (Table 3, Model 3). However, this effect occurred in the absence of a substantial zero-order correlation between the LOT-R and CD56^{dim}CD57+ NK cells (i.e., it does not reflect the resistance of a zero-order relationship to additional controls; see Table 1). Furthermore, in the presence of substantial overlap between the LOT-R and relative resources, the meaning and validity of the LOT-R after residualizing on these resources is unknown (Lynam, Hoyle, & Newman, 2006).

Depressive symptoms and NK terminal maturity

Even within this psychologically healthy sample, resources could influence mood, which in turn could mediate effects on NK terminal maturity. However, depressive symptoms were not significantly related to percentages of CD56^{dim}CD57+ NK cells in the total sample, either before (see Table 1) or after including age group in the model ($\Delta R^2 = .01$, $\beta = -.16$, $t(69) = -1.01$, $p > .05$). Depressive symptoms were likewise not significantly related to percentages of CD56^{dim}CD57+ NK cells in the older women, either before (see Table 1) or after including age in the model ($\Delta R^2 = .05$, $\beta = -.23$, $t(31) = -1.40$, $p > .05$). Therefore, the effects of resources could not be accounted for by depressive symptoms.

Discussion

Aging brings a number of immunological changes that could contribute to increased vulnerability to infectious disease and cancer (Effros, in press; Pawelec et al., 2005; Solana et al., 2006). In NK cells, the cell surface marker CD57 correlates with low constitutive replication and markedly deficient replication in response to stimulatory challenges, leading to the characterization of these cells as "terminally differentiated" and the conclusion that many of them may have reached replicative senescence, although it is important to note that these cells retain their killer functions (Björkström et al., 2010; Hayhoe et al., 2010; Lopez-Verges et al., 2010, p. 3865; Lutz et al., 2011). In the present study, both older age and fewer resources were associated with a higher proportion of CD57+ NK cells. This finding

therefore adds to previous findings that psychosocial factors can contribute to immunological aging (Damjanovic et al., 2007; Epel et al., 2004; Nakamura et al., 1999; Spielmann et al., 2011; Wikgren et al., 2012). The present study also builds on that literature by correlating psychosocial factors and immunological aging in both younger and older adults. Most previous studies that have focused on markers associated with replicative senescence have examined middle-aged adults (Epel et al., 2004; Nakamura et al., 1999; Spielmann et al., 2011; Wikgren et al., 2012). Like those studies, we found that poorer psychosocial status was associated with premature NK terminal maturation among younger women. However, we also found that better psychosocial status associated with less NK terminal maturation in older women. As illustrated in Figure 1, for this particular index of immunological aging, an older woman with many resources appeared similar to a younger woman with few resources. This is a notable pattern when one considers the large age difference between the groups.

Resources and immunological aging: Which, when, and for whom

The resource domains – social, financial, psychological, and status-skill – were substantially correlated with each other. The overlap in resources was expected, as previous research suggests that the presence of resources in one domain facilitates the acquisition or retention of resources in other domains. For example, longitudinal studies found that a psychological resource (optimism) predicted the acquisition of both social and financial resources, and resources in turn increased optimism (Brissette, Scheier, & Carver, 2002; Segerstrom, 2007). However, relative financial resources correlated with terminal maturation in NK cells beyond this common variance, and in the total sample (although not in the older women only), household income correlated with terminal maturation in NK cells above and beyond that relationship. These data therefore add not only to the substantial literature linking measures of SES to better health, they also add to the much smaller literature linking subjective and objective SES to biomarkers in older adults (Demakakos et al., 2008). Of interest, Demakakos and colleagues (2008) noted that “wealth was the only objective indicator of SES that explained some of the associations between SSS [subjective social status] and health”, including biomarkers such as triglycerides, in older women (p. 335). Likewise, in the present study, among the older women, it was the shared variance between household income and relative financial resources that best correlated with the degree of NK terminal maturity.

When and for whom different resource classes are protective against immunological aging and affect other biological and health parameters is an important question. The present findings suggest that the context in which resources are assessed may influence the results. These data were collected in the latter part of 2007 through 2008. This period corresponded to the onset of the financial crisis; during the dates bracketing this study, two major US stock indices, the Dow Jones Industrial Average and the Standard & Poor's 500, lost 32% and 38% of their value, respectively. In a context such as financial crisis, individuals may be most affected by the degree to which they feel secure in their financial resources. In contrast, at times when endings, including mortality, are salient, they may be more affected by the degree to which they feel secure in their social resources (Carstensen et al., 1999; Fredrickson & Carstensen, 1990). As our older women were selected for good health, they might not have had a strong sense of the end of life approaching and thus resembled the younger women in the resource-NK relationship, but other contexts might result in differential effects of resource classes in older versus younger age. Finally, there may be individual differences other than age that may be important. For example, social resources may be more important to people high in personality traits such as agreeableness, whereas status-skill resources may be more important to people high in personality traits such as social dominance.

Depressive symptoms were not significantly associated with immunological aging, and so a pathway from resources to NK cells via depressive symptoms was not supported. By design, this was a psychologically and physically healthy sample, primarily so as not to confound aging with disease. Women in this sample were also mainly well educated and middle class, and they typically appraised themselves as having slightly more resources than the average woman their age, suggesting that they were generally satisfied. Therefore, restriction of range, particularly in depressive symptoms but also possibly in resources, was present. However, there was sufficient variability in both depressive symptoms and resources for a significant relationship between those two to emerge (see Table 1), and sufficient variability in resources for a significant relationship between them and CD57 expression on NK cells to emerge. The emergence of these relationships in this sample suggests that accelerated immunological aging may not be a phenomenon limited to highly stressful circumstances (e.g., dementia caregiving; Damjanovic et al., 2007). Instead, individual differences in the healthy range, such as between having adequate and abundant resources, may also play a role. Within this healthy range, future research might also consider alternative mediators. For example, individual differences in positive mood rather than depressive symptoms might mediate the effect of resources (Segerstrom & Sephton, 2010; Steptoe et al., 2009).

Natural killer cell aging: Potential mechanisms and consequences

NK cell aging is different from that in other immunological subsystems insofar as most NK cells turn over relatively quickly, so the “aging” of these cells presumably occurs over a short period of time. Any condition that drives faster NK cell division and proliferation can accelerate this progression, as replicative senescence in general and CD57 expression in particular are related to the number of previous replications (Lopez-Verges et al., 2010). It is important to note that the women in this study were screened for overt conditions such as cancer or infection that could drive faster NK cell replication, but subclinical processes may be at work. For example, most people are infected with cytomegalovirus (CMV) by young adulthood, and the infection persists latently throughout life. Recent evidence indicates that both chronic and acute CMV infection increase the percentage of CD57+ NK cells activated by CMV, suggesting that the cell proliferation associated with the virus leads to terminal maturity and replicative senescence in these cells (Lopez-Verges et al., 2011). Psychosocial factors have been linked to reactivation of latent viral infection, suggesting one pathway by which resources could correlate with a higher percentage of CD57+ cells (Glaser et al., 1991). Likewise, and congruent with the present findings, control of latent CMV infection was poorer with lower household income, and this relationship was true across a large age range (25 years to over 75 years; Dowd & Aiello, 2009). Another potential pathway is poor DNA repair, as NK cells are also stimulated by and proliferate in the presence of damaged self cells, and such damage has been associated with stress (Kiecolt-Glaser, Stephens, Lipetz, Speicher, & Glaser, 1985). Finally, recent evidence suggests that health behavior, particularly as it affects aerobic fitness, may retard immunosenescence (Spielmann et al., 2011). “Almost all [health behaviors] vary by socioeconomic status” (Adler & Newman, 2002, p. 68), and pathways such as physical activity, sleep, and smoking could account for the observed effects. Identifying the mechanisms driving the relationship of financial resources to CD57 expression on NK cells is an important direction for future research.

Likewise, much remains to be learned about the clinical implications of high percentages of CD57+ NK cells. Terminal maturation and replicative senescence in related cells have been suspected to increase susceptibility to viral infections and poor prognosis in some cancers (Focosi, Bestagno, Burrone, & Petrini, 2010) and the likelihood of low-grade inflammation that could contribute to multiple age-related diseases (Effros, in press; Ershler & Keller, 2000; Ross, 1999). It is important to note that NK cell proliferation may be particularly important for a robust response to novel stimuli because of the containment role of NK cells

until other cells come “on line”. Older adults are more susceptible than younger adults to poor health outcomes associated with novel and mutating viruses, particularly influenza (Sprenger, Mulder, Beyer, van Strik, & Masurel, 1993). The accumulation of terminally mature NK cells may contribute to this susceptibility. In addition, older adults who were nonresponders to the influenza vaccine (i.e., they produced an insufficient amount of antibody to protect against subsequent viral infection) had a significantly higher percentage of CD57+ NK cells than responders (Trzonkowski et al., 2003). Because NK cells are not involved in antibody production, this finding suggests that the percentage of CD57+ NK cells may be an important marker for immunosenescence in general.

Limitations and future directions

The present study is limited insofar as the sample consisted only of women, and only extreme age groups. Furthermore, different strategies were used to recruit older and younger women, which may have resulted in their being drawn from somewhat different populations. This design was selected to reduce variability due to sex and maximize the ability to detect age differences in a relatively small sample; however, future investigations should expand the model to include effects of gender and other stages in the lifespan. Another limitation involves the focus only on percentages in NK cell subsets. Cell counts were not performed on these samples; therefore, we could not address the total number of cells as they might have varied by age and resources. The results should be interpreted only as they pertain to the ratios associated with subsets from a cell type (NK cells) that may have varied in total number. However, NK number does not differ significantly between the age groups studied here, and so this is not likely to be a major confounder of these results (Ligthart, Shuit, & Hijmans, 1989). This was also a cross-sectional study. Because NK cells typically have a shorter lifespan than other lymphocytes (e.g., T cells), the rate of NK cell aging may fluctuate more than other indices of immunological aging, and this parameter may be well suited to longitudinal designs that could link changes in resources to changes in NK terminal maturity.

Conclusion

These findings provide support for the hypothesis that the sense that one has either substantial or few resources may affect age-associated aspects of the microenvironment in which NK cells mature to senescence. Which resources are most important may be context dependent; financial resources were most important to this sample in a time of financial insecurity. In addition, longitudinal studies may illuminate whether it is the gain and abundance or loss and absence of resources that are more important for NK cell aging. These findings provide support for the hypothesis that NK cell terminal maturity is sensitive to psychosocial factors and a valuable parameter for investigations in aging, immunology, and health.

Acknowledgments

The study was supported by the NIH (AI056506, AG026530, AG033629), the University of Kentucky Clinical Research Development and Operations Center (RR02602), and the Sanders-Brown Center on Aging (AG05144).

References

- Adler NE, Newman K. Socioeconomic disparities in health: Pathways and policies. *Health Affairs*. 2002; 21:60–76. [PubMed: 11900187]
- Banks, J.; Karlsen, S.; Oldfield, Z. Socio-economic position. In: Marmot, M.; Banks, J.; Blundell, R.; Lessof, C.; Nazroo, J., editors. *Health, Wealth, and Lifestyles of the Older Population in England: The 2002 English Longitudinal Study of Ageing*. London, England: Institute for Fiscal Studies; 2003. p. 71-90.

- Björkström NK, Riese P, Heuts F, Andersson S, Fauriat C, Ivarsson MA, Malmberg KJ. Expression patterns of NKG2A, KIR, and CD57 define a process of CD56^{dim} NK-cell differentiation uncoupled from NK-cell education. *Blood*. 2010; 116:3853–3864. [PubMed: 20696944]
- Brisette I, Scheier MF, Carver CS. The role of optimism in social network development, coping, and psychological adjustment during a life transition. *Journal of Personality and Social Psychology*. 2002; 82:102–111. [PubMed: 11811628]
- Carstensen LL. Social and emotional patterns in adulthood: Support for socioemotional selectivity theory. *Psychology and Aging*. 1992; 7:331–338. [PubMed: 1388852]
- Carstensen LL, Isaacowitz DM, Charles ST. Taking time seriously: A theory of socioemotional selectivity. *American Psychologist*. 1999; 54:165–181. [PubMed: 10199217]
- Cohen S, Alper CM, Doyle WJ, Adler N, Treanor JJ, Turner RB. Objective and subjective socioeconomic status and susceptibility to the common cold. *Health Psychology*. 2008; 27:268–274. [PubMed: 18377146]
- Damjanovic AK, Yang H, Glaser R, Kiecolt-Glaser JK, Weng NP. Accelerated telomere erosion is associated with a declining immune function of caregivers of Alzheimer's disease patients. *Journal of Immunology*. 2007; 179:4249–4254.
- Demakakos P, Nazroo J, Breeze E, Marmot M. Socioeconomic status and health: The role of subjective social status. *Social Science & Medicine*. 2008; 67:330–340. [PubMed: 18440111]
- Diener E, Fujita F. Resources, personal strivings, and subjective well-being: A nomothetic and idiographic approach. *Journal of Personality and Social Psychology*. 1995; 68:926–935. [PubMed: 7776188]
- Dowd JB, Aiello A. Socioeconomic differentials in immune response in the U.S. *Epidemiology*. 2009; 20:902–908. [PubMed: 19797966]
- Effros RB. Stress and immune system aging. In: Segerstrom, SC., editor. *Oxford Handbook of Psychoneuroimmunology*. New York: Oxford University Press; (in press)
- Effros RB, Pawelec G. Replicative senescence of T cells: Does the Hayflick Limit lead to immune exhaustion? *Immunology Today*. 1997; 18:450–454. [PubMed: 9293162]
- Epel ES. Telomeres in a life-span perspective: A new “psychobiomarker”? *Current Directions in Psychological Science*. 2009; 18:6–10.
- Epel ES, Blackburn EH, Lin J, Dhabhar FS, Adler NE, Morrow JD, Cawthon RM. Accelerated telomere shortening in response to life stress. *PNAS*. 2004; 101:17312–17315. [PubMed: 15574496]
- Ershler WB, Keller ET. Age-associated increased interleukin-6 gene expression, late-life diseases, and frailty. *Annual Review of Medicine*. 2000; 51:245–270.
- Focosi D, Bestagno M, Burrone O, Petrini M. CD57+ T lymphocytes and functional immune deficiency. *Journal of Leukocyte Biology*. 2010; 87:107–116. [PubMed: 19880576]
- Fredrickson BL, Carstensen LL. Choosing social partners: How old age and anticipated endings make people more selective. *Psychology and Aging*. 1990; 5:335–347. [PubMed: 2242238]
- Gallo LC, Bogart LM, Vranceanu AM, Matthews KA. Socioeconomic status, resources, psychological experiences, and emotional responses: A test of the reserve capacity model. *Journal of Personality and Social Psychology*. 2005; 88:386–399. [PubMed: 15841865]
- Geers AL. Examining the relationship between specific expectations and optimism and pessimism. *Representative Research in Social Psychology*. 2000; 24:33–40.
- Glaser R, Pearson GR, Jones JF, Hillhouse J, Kennedy S, Mao H, Kiecolt-Glaser JK. Stress-related activation of Epstein-Barr virus. *Brain, Behavior, and Immunity*. 1991; 5:219–232.
- Graham JE, Christian LM, Kiecolt-Glaser JK. Stress, age, and immune function: Toward a lifespan approach. *Journal of Behavioral Medicine*. 2006; 29:389–400. [PubMed: 16715331]
- Hayhoe RPG, Henson SM, Akbar AM, Palmer DP. Variation of human natural killer cell phenotypes with age: Identification of a unique KLRG-negative subset. *Human Immunology*. 2010; 71:676–681. [PubMed: 20394788]
- Hobfoll SE. Conservation of resources: A new attempt at conceptualizing stress. *American Psychologist*. 1989; 44:513–524. [PubMed: 2648906]

- Hobfoll SE, Lilly RS. Resources conservation as a strategy for community psychology. *Journal of Community Psychology*. 1993; 21:128–148.
- Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine*. 2010; 7:e1000316.10.1371/journal.pmed.1000316 [PubMed: 20668659]
- House JS, Landis KR, Umberson D. Social relationships and health. *Science*. 1988; 241:540–545. [PubMed: 3399889]
- Kiecolt-Glaser JK, Stephens RE, Lipetz PD, Speicher CE, Glaser R. Distress and DNA repair in human lymphocytes. *Journal of Behavioral Medicine*. 1985; 8:311–320. [PubMed: 2936891]
- Lang FR, Carstensen LL. Time counts: Future time perspective, goals, and social relationships. *Psychology and Aging*. 2002; 17:125–139. [PubMed: 11931281]
- Levy B, Slade M, Kunkel S, Kasl S. Longevity increased by positive self-perceptions of aging. *Journal of Personality and Social Psychology*. 2002; 83:261–270. [PubMed: 12150226]
- Ligthart GJ, Schuit HRE, Hijmans W. Natural killer cell function is not diminished in the healthy aged and is proportional to the number of NK cells in the peripheral blood. *Immunology*. 1989; 68:396–402. [PubMed: 2592014]
- Lipkus IM, Martz JM, Panter AT, Drigotas SM, Feaganes JR. Do optimists distort their predictions for future positive and negative events? *Personality and Individual Differences*. 1993; 15:577–589.
- Lopez-Verges S, Milush JM, Pandey S, York VA, Arakawa-Hoyt J, Pircher H, Lanier LL. CD57 defines a functionally distinct population of mature NK cells in the human CD56^{dim}CD16+ NK-cell subset. *Blood*. 2010; 116:3865–3974. [PubMed: 20733159]
- Lopez-Verges S, Milush JM, Schwartz BS, Pando MJ, Jarjoura J, York VA, Lanier LL. Expansion of a unique CD57+NKG2C^{hi} natural killer cell subset during acute human cytomegalovirus infection. *PNAS*. 2011; 108:14725–14732. [PubMed: 21825173]
- Lutz CT, Karapetyan A, Al-Attar A, Shelton BJ, Holt KJ, Tucker JH, Presnell SR. Human NK cells proliferate and die in vivo more rapidly than T cells in healthy young and elderly adults. *Journal of Immunology*. 2011; 186:4590–4598.
- Lynam DR, Hoyle RH, Newman JP. The perils of partialling: Cautionary tales from aggression and psychopathy. *Assessment*. 2006; 13:328–341. [PubMed: 16880283]
- Manuck SB, Phillips JE, Gianaros PJ, Flory JD, Muldoon MF. Subjective socioeconomic status and presence of the metabolic syndrome in midlife community volunteers. *Psychosomatic Medicine*. 2010; 72:35–45. [PubMed: 19933505]
- Marmot MG, Davey Smith G, Stansfeld S, Patel C, North F, Head J, White I, Brunner E, Feeney A. Health inequalities among British civil servants: The Whitehall II study. *Lancet*. 1991; 337:1387–1393. [PubMed: 1674771]
- Nakamura H, Nagase H, Yoshida M, Ogino K. Natural killer (NK) cell activity and NK cell subsets in workers with a tendency of burnout. *Journal of Psychosomatic Research*. 1999; 46:569–578. [PubMed: 10454173]
- Pawelec G, Akbar A, Caruso C, Grubeck-Loebenstein B, Solana R, Wikby A. Human immunosenescence: Is it infectious? *Immunological Reviews*. 2005; 205:257–268. [PubMed: 15882359]
- Powell LH, Shahabi L, Thoresen CE. Religion and spirituality: Linkages to physical health. *American Psychologist*. 2003; 58:26–52.
- Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*. 1977; 1:385–401.
- Riediger M, Schmiedek F, Wagner GG, Lindenberger U. Seeking pleasure and seeking pain: Differences in prohedonic and contra-hedonic motivation from adolescence to old age. *Psychological Science*. 2009; 20:1529–1535. [PubMed: 19891749]
- Roberts BW, Kuncel NR, Shiner R, Caspi A, Goldberg LR. The power of personality: The comparative validity of personality traits, socioeconomic status, and cognitive ability for predicting important life outcomes. *Perspectives on Psychological Science*. 2007; 2:313–345.
- Ross R. Atherosclerosis – an inflammatory disease. *New England Journal of Medicine*. 1999; 340:115–126. [PubMed: 9887164]

- Sansoni P, Cassarizza A, Brianti V, Fagnoni F, Snelli G, Franceschi C. Lymphocyte subsets and natural killer cell activity in healthy old people and centenarians. *Blood*. 1993; 82:2767–2773. [PubMed: 8219229]
- Scheier MF, Carver CS, Bridges MW. Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): A reevaluation of the Life Orientation Test. *Journal of Personality and Social Psychology*. 1994; 67:1063–1078. [PubMed: 7815302]
- Segerstrom SC. Optimism and resources: Effects on each other and on health over 10 years. *Journal of Research in Personality*. 2007; 41:772–786. [PubMed: 17710186]
- Segerstrom SC. Resources, stress, and immunity: An ecological perspective on human psychoneuroimmunology. *Annals of Behavioral Medicine*. 2010; 40:114–125. [PubMed: 20526755]
- Segerstrom SC, Miller GE. Psychological stress and the human immune system: A meta-analytic study of 30 years of inquiry. *Psychological Bulletin*. 2004; 130:601–630. [PubMed: 15250815]
- Segerstrom SC, Sephton SE. Optimistic expectancies and cell-mediated immunity: The role of positive affect. *Psychological Science*. 2010; 21:448–455. [PubMed: 20424083]
- Singh-Manous A, Marmot MG, Adler NE. Does subjective social status predict health and change in health status better than objective status? *Psychosomatic Medicine*. 2005; 67:855–861. [PubMed: 16314589]
- Solana R, Pawelec G, Tarazona R. Aging and innate immunity. *Immunity*. 2006; 24:491–494. [PubMed: 16713963]
- Spielmann G, McFarlin BK, O'Connor DP, Smith PJW, Pircher H, Simpson RJ. Aerobic fitness is associated with lower proportions of senescent blood T-cells in man. *Brain, Behavior, and Immunity*. 2011; 25:1521–1529.
- Sprenger MJW, Mulder PGH, Beyer WEP, van Strik R, Masurel N. Impact of influenza on mortality in relation to age and underlying disease, 1967–1989. *International Journal of Epidemiology*. 1993; 22:334–340. [PubMed: 8505193]
- Steptoe A, Dockray S, Wardle J. Positive affect and psychobiological processes relevant to health. *Journal of Personality*. 2009; 77:1747–1776. [PubMed: 19796062]
- Taylor SE, Stanton AL. Coping resources, coping processes, and mental health. *Annual Review of Clinical Psychology*. 2007; 3:377–401.
- Trzonkowski P, Myśliwska J, Szmit E, Wiśkiewicz J, Łukaszuk K, Brydak LB, Machała M, Myśliwski A. Association between cytomegalovirus infection, enhanced proinflammatory response and low level of anti-hemagglutinins during the anti-influenza vaccination – an impact of immunosenescence. *Vaccine*. 2003; 21:3826–3836. [PubMed: 12922116]
- Vivier E, Raulet DH, Moretta A, Caligiuri MA, Zitvogel L, Lanier LL, Yokoyama WM, Ugolini S. Innate or adaptive immunity? The example of natural killer cells. *Science*. 2011; 331:44–49. [PubMed: 21212348]
- Wikgren M, Maripuu M, Karlsson T, Nordfjäll K, Bergdahl J, Norrback KF. Short telomeres in depression and the general population are associated with a hypocortisolemic state. *Biological Psychiatry*. 2012; 71:294–300. [PubMed: 22055018]

Appendix

Relative resource measure items from the Conservation of Resources Evaluation

Social

Affection from others
 Companionship
 Family stability
 Help with tasks at home

Intimacy with at least one friend
 Intimacy with one or more family members
 Involvement in organizations with others who have similar interests
 Involvement with church, synagogue, etc.
 Loyalty of friends

Financial

Adequate clothing
 Adequate financial credit
 Adequate food
 Adequate home furnishings
 Adequate income
 Financial assets
 Financial help if needed
 Financial stability
 Housing that suits my needs
 Larger home than I need
 Medical insurance
 Money for extras
 Money for transportation
 More clothing than I need
 Necessary home appliances
 Personal transportation (car, truck, etc.)
 Sense of pride in myself
 Retirement security (financial)
 Savings or emergency money

Status-skill

Ability to communicate
 Ability to organize tasks
 Acknowledgement of my accomplishments
 People I can learn from
 Positively challenging routine
 Role as a leader

Psychological

Feeling independent
 Feeling that I am accomplishing my goals
 Feeling that I am successful
 Feeling that I have control over my life
 Feeling that I know who I am
 Feeling that my future success depends on me
 Feeling that my life has meaning or purpose
 Feeling that my life is peaceful
 Feeling valuable to others
 Hope

Knowing where I am going with my life

Motivation to get things done

Positive feelings about myself

Self-discipline

Sense of commitment

Sense of humor

Sense of optimism

Stamina or endurance

Note. From “Resource Conservation as a Strategy for Community Psychology,” by S.E. Hobfoll and R.S. Lilly, 1993, *Journal of Community Psychology*, 21, p. 137. Copyright 1993 by John Wiley and Sons. Reprinted with permission.

Figure 1.
Effects of age group and resources (from low, -1 SD, to high, $+1$ SD) on percent of NK cells expressing CD57 in younger (M age = 27) and older (M age = 82) women

Table 1

Convergent and discriminant validity of the resource measure and comparisons between older (N = 34), and younger (N = 38) women.

	1	2	3	4	5	6	7	8	9	10	M (SD)	
											Older	Younger
1. Social resources	-	.64*	.75*	.75*	.49*	.18	.33	.09	-.17	-.17	5.4 (0.9)	4.8 (0.9)**
2. Financial resources	.46*	-	.75*	.69*	.01	.36	.26	.13	.18	-.47*	5.5 (0.9)	4.4 (0.8)**
3. Psychological resources	.62*	.60*	-	.91*	.17	.13	.48*	.27	.00	-.32	5.5 (1.0)	5.3 (0.7)
4. Status-skill resources	.51*	.44*	.68*	-	.11	-.02	.49*	.25	-.10	-.27	5.2 (1.1)	5.2 (0.7)
5. Religious attendance	.47*	.32*	.35*	.29	-	.13	.28	-.10	-.37*	.11	2.1 (1.8)	2.8 (1.7)
6. Household income (\$K) ^a	.18	.41*	.24	.17	.46*	-	.07	.32	.26	-.38	37.0 (26)	33.2 (26)
7. LOT-R	.32*	.08	.40*	.08	.40*	.05	-	.26	.19	-.24	4.0 (0.7)	3.9 (0.7)
8. Education level	.09	.09	.08	.05	-.02	.02	.22	-	.28	-.17	3.6 (1.5)	4.7 (1.1)**
9. CES-D	-.36*	-.10	-.32	-.23	-.33*	-.22	-.53*	-.16	-	-.20	3.4 (2.8)	3.1 (3.2)
10. % CD56 ^{dim} CD57+ NK cells	-.26	-.23	.00	-.18	-.22	-.32*	-.16	.02	-.05	-	57 (21)	47 (17)**

Note. Correlations for younger women (N = 38) are shown below the diagonal; older women (N = 34), above the diagonal LOT-R: Life Orientation Test – Revised (dispositional optimism). CES-D: Center for Epidemiological Studies – Depression (depressive symptoms).

* $p < .05$

** Difference between younger and older women is significant at $p < .05$

^a Coded to the median of each income group (e.g., \$10,000 – \$20,000 was coded as \$15,000). Correlations for the older women are pooled estimates from multiple imputation ($m = 10$).

\$watermark-text

\$watermark-text

\$watermark-text

Table 2

Results of hierarchical regression models predicting CD57 expression on CD56^{dim} NK cells from age group and total relative resources (Model 1) and age and total relative resources within the older women (Model 2)

	R ²	ΔR ²	B (SE)	β	t
Model 1 (N = 72)					
Step					
1 Age group	.07		10.3 (4.5)	.26	2.27*
2 Relative resources	.15	.08	-6.7 (2.7)	-.29	2.49*
3 Age group* resources	.15	.00	-1.8 (5.7)	-.06	0.31
Model 2 (N = 34)					
Step					
1 Age (years)	.10		1.5 (0.8)	.32	1.89
2 Relative resources	.25	.15	-8.6 (3.4)	-.40	2.52*
3 Age* resources	.27	.02	0.9 (1.0)	.17	0.95

Note. Age group was coded 1 = older and 0 = younger. Resources were scaled with M = 0 and SD = 1.

* p < .05

Table 3

Results of hierarchical regression models predicting CD57 expression on CD56^{dim} NK cells from age group and individual resources.

Step	Model 1			Model 2			Model 3 ^a		
	B (SE)	β	t	B (SE)	β	t	B (SE)	t	
1 Age group	10.3 (4.5)	.26	2.27 *	19.5 (5.5)	.50	3.56 *	11.2 (4.5)	2.48 *	
2 Relative resources									
Social	-1.1 (3.2)	-.06	0.34	-6.7 (4.3)	-.33	1.55	-2.3 (3.4)	0.67	
Financial	-9.4 (3.5)	-.48	2.65 *	-6.0 (4.5)	-.31	1.33	-6.5 (3.7)	1.74	
Psychological	5.8 (4.7)	.30	1.24	13.9 (7.1)	.62	1.97	8.5 (4.8)	1.75	
Status-skill	-4.0 (4.0)	-.20	1.00	-6.3 (6.1)	-.29	1.03	-5.7 (4.0)	1.42	
3 Interaction with Age group									
Social				11.9 (6.5)	.42	1.83			
Financial				-7.6 (7.0)	-.26	1.08			
Psychological				-13.4 (9.5)	-.56	1.40			
Status-skill				5.8 (8.4)	.25	0.69			
3 Absolute resources									
Religious attendance							2.4 (1.5)	1.59	
Household income							-2.6 (1.0)	2.56 *	
LOT-R							-8.6 (3.7)	2.29 *	
Education							1.6 (1.8)	0.89	

^a Pooled estimates from regression model using multiple imputation (m = 10) to account for missing household income data. Pooling does not yield a standardized beta weight.

* $p < .05$

Table 4

Results of hierarchical regression models predicting CD57 expression on CD56^{dim} NK cells from age and individual resources among the older women (N=34) only.

Step	Model 1				Model 2				Model 3 ^a			
	B (SE)	β	t		B (SE)	β	t		B (SE)	β	t	
1 Age	1.6 (0.8)	.32	1.89		1.4 (1.3)	.28	1.06		1.4 (0.8)	1.73		
2 Relative resources												
Social	4.6 (5.0)	.21	0.92		5.2 (5.6)	.23	0.94		3.0 (7.1)	0.43		
Financial	-15.2 (5.3)	-.65	2.86*		-18.1 (6.5)	-.79	2.77*		-9.6 (7.4)	1.30		
Psychological	3.2 (7.5)	.18	0.43		6.2 (9.2)	.30	0.67		0.7 (8.3)	0.08		
Status-skill	-3.8 (6.5)	-.23	0.59		-3.9 (7.5)	-.21	0.52		-2.2 (8.4)	0.26		
3a Interaction with age												
Social					-1.4 (1.9)	-.25	0.76					
Financial					2.2 (2.2)	.45	1.03					
Psychological					-0.5 (3.1)	-.10	0.15					
Status-skill					5.8 (8.4)	.25	0.69					
3b Absolute resources												
Religious attendance									2.3 (2.7)	0.84		
Household income									-2.3 (2.3)	0.98		
LOT-R									-6.6 (5.9)	1.12		
Education									1.9 (3.1)	0.61		

^aPooled estimates from regression model using multiple imputation (m = 10) to account for missing household income data. Pooling does not result in a standardized beta weight.

* $p < .05$