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Does Hugging Provide Stress-Buffering Social Support? A Study of Susceptibility to Upper Respiratory Infection and Illness

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Abstract

Perceived social support has been hypothesized to protect against the pathogenic effects of stress. How such protection might be conferred, however, is not well understood. Using a sample of 404 healthy adults, we examined the roles of perceived social support and received hugs in buffering against interpersonal stress-induced susceptibility to infectious disease. Perceived support was assessed by questionnaire, and daily interpersonal conflict and receipt of hugs were assessed by telephone interviews on 14 consecutive evenings. Subsequently, participants were exposed to a virus that causes a common cold and were monitored in quarantine to assess infection and illness signs. Perceived support protected against the rise in infection risk associated with increasing frequency of conflict. A similar stress-buffering effect emerged for hugging, which explained 32% of the attenuating effect of support. Among infected participants, greater perceived support and more-frequent hugs each predicted less-severe illness signs. These data suggest that hugging may effectively convey social support.

Keywords

health, interpersonal interaction, psychological stress, social support, touch, stress buffering, open data

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Social support refers to the psychological and material resources provided by a social network to benefit an individual's ability to cope with stressful events (e.g., Cassel, 1976; Cobb, 1976; Cohen, 2004; Thoits, 1986). The perceived availability of social support has been found to protect against the potential of stressful events to elicit psychological distress, depression, and anxiety (for reviews, see Cohen & Wills, 1985; Kawachi & Berkman, 2001; Schwartzer & Leppin, 1989). Perceived support may also protect against stress-elicited increases in risk for physical morbidity and mortality (Falk, Hanson, Isacsson, & Ostergren, 1992; Rosengren, Orth-Gomer, Wedel, & Wilhelmsen, 1993). Offering support of any kind can be viewed as an expression of empathy, caring, and reassurance, resources thought to be most beneficial in the face of stressful events (Cobb, 1976). However, the evidence for stress buffering derives from studies assessing global perceptions of support, and little is known about the specific behaviors most effective in conveying the availability of these resources to other people (cf. Gottlieb, 1988; Lewis & Rook, 1999; Uchino, 2004).

Several investigators have proposed that nonsexual, caring physical touch, such as hugging or hand holding, is an important means of conveying empathy, caring, and reassurance (e.g., Grewen, Anderson, Girdler, & Light, 2003; Holt-Lunstad, Birmingham, & Light, 2008; Reis & Patrick, 1996). In fact, laboratory studies have generally found that touch from a trusted other buffers the usual

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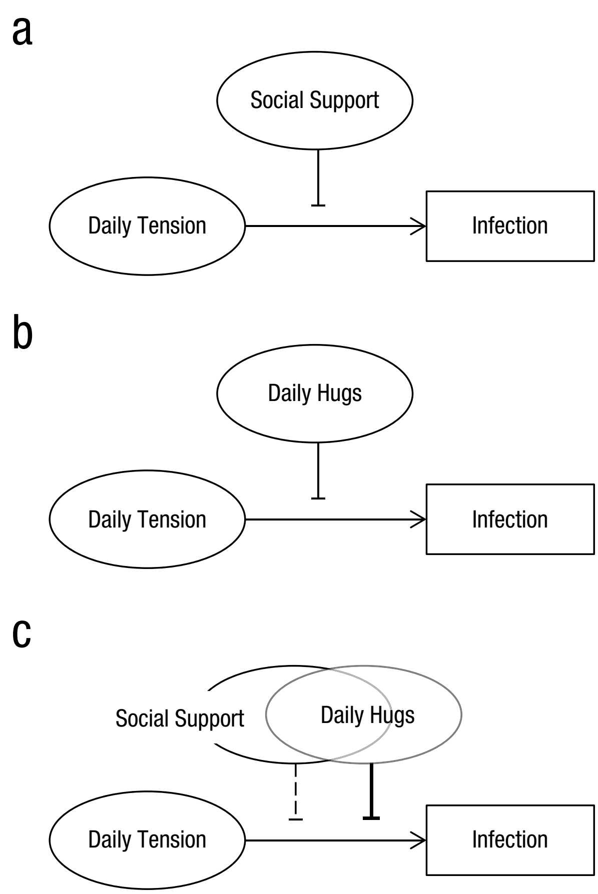

Fig. 1. Illustration of the hypotheses. We predicted that (a) social support and (b) daily hugs would moderate the association between daily social tension and risk of infection. We further expected (c) that the buffering effect of social support would be partly or wholly attributable to the attenuating effect of hugs on infection risk.

effects of stress on pain (Master et al., 2009), as well as on activation of autonomic pathways (Ditzen et al., 2007; Grewen et al., 2003), the hypothalamic-pituitary-adrenal axis (Ditzen et al., 2007), and the brain (Coan, Schaefer, & Davidson, 2006). However, evidence for whether such nonverbal gestures buffer stress effects on disease is lacking, as is evidence showing whether touch buffers stress effects in natural settings (but see suggestive evidence in Ditzen, Hoppmann, & Klumb, 2008).

Interpersonal stressors, especially conflicts, have been found to have potent aversive effects on psychological well-being (e.g., Bolger, DeLongis, Kessler, & Schilling, 1989; Rook, 1984, 1992) and to activate stress physiology and dysregulate immune response (Kiecolt-Glaser & Newton, 2001). At the same time, people experiencing interpersonal stressors may be particularly receptive to the stress-buffering effects of behaviors indicating care and intimacy, such as physical touch. That is, social wounds may be best healed by the intimate behaviors of other people. Touch itself may be an especially effective means of conveying support in that it is *invisible*—that is, it is unlikely to provoke feelings of weakness or neediness on the part of the recipient (Bolger & Amarel, 2007; Jakubiak & Feeney, 2014)—and it is easy to enact well.

Our own work suggests that interpersonal stressors are associated with an increased risk of developing a cold when participants are experimentally exposed to a common cold virus (Cohen et al., 1998; Cohen, Tyrrell, & Smith, 1991). This increased susceptibility under stress is attributable to stress-associated risk of the virus replicating (infection), stress-associated production of signs (objective markers) of illness in infected persons, or both (e.g., Cohen, Doyle, & Skoner, 1999; Cohen et al., 1991). Here, we examined whether global perceptions of social support and the actual receipt of physical touch during daily life—being hugged—attenuate the association of an interpersonal stressor (social conflict) with subsequent risk for infection, cold signs, and clinical disease in response to an experimentally administered cold virus. We expected that more-frequent conflict would be associated with increased susceptibility. However, these associations would be attenuated (buffered) among people who perceive higher levels of social support and among those who receive hugs with greater frequency (see Figs. 1a and 1b, which use infection as an example). We also expected that the buffering effects of perceived support would be partly or wholly attributable to being hugged on a regular basis (see Fig. 1c).

Method

Participants

The analyses presented here combined archival data from two viral-challenge studies that followed a common set of procedures. These procedures included a physical exam, questionnaire assessments of demographics and social support, a 2-week evening interview protocol assessing daily interpersonal interactions, and subsequent participation in a viral-challenge trial. The total sample consisted of 406 participants (193 in Study 1 and 213 in Study 2). Study 1 was conducted between 2000 and 2004, and Study 2 was conducted between 2007 and 2011. The maximum available sample size was employed. The participants were healthy adults between the ages of 18 and 55 years (M = 33.5, SD = 10.5).

Participants from both studies were recruited from the Pittsburgh, Pennsylvania, metropolitan area via newspaper advertisements and community postings. All participants provided informed consent and received financial compensation for participation. Study procedures were approved by the appropriate institutional review boards. The total sample was 46.3% female (53.7% male) and 38.4% non-White (32.0% African American; 1.5% Asian or Pacific Islander; 0.5% Native American, Eskimo, or Aleut;

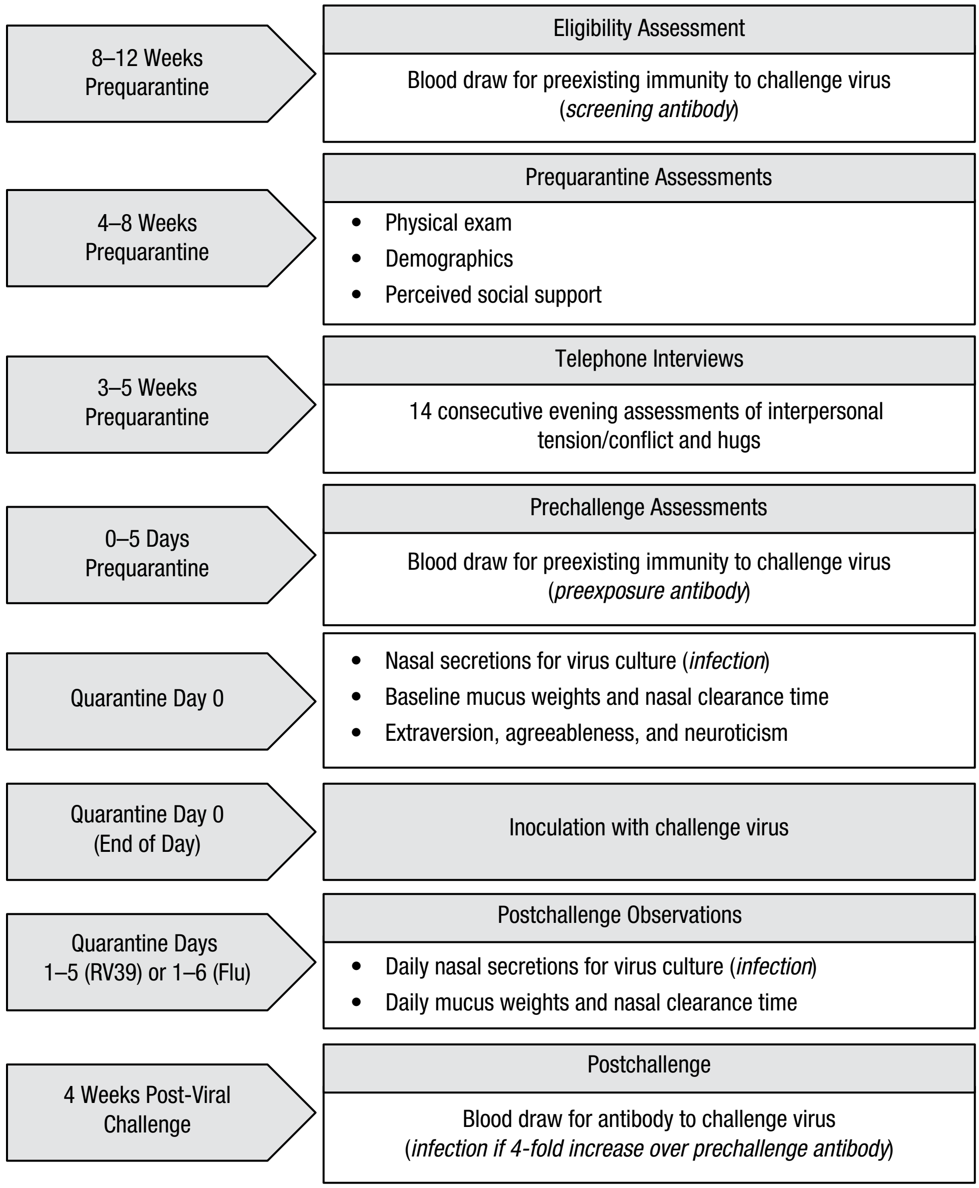

Fig. 2. Temporal sequence of study activities. RV39 = rhinovirus 39.

1.0% Hispanic or Latino; and 3.5% of "other" race or ethnicity). One quarter (24.3%) of the sample was married (only one member of a couple could participate), 27.3% had less than or equal to a high school education, and 25.5% had earned at least a bachelor's degree. Two participants were missing data on relevant covariates and thus were excluded from the present analyses, which left a final sample of 404.

Procedure

Figure 2 depicts the temporal sequence of study activities. Volunteers underwent medical screenings and were excluded from study eligibility if they had a history of psychiatric illness, asthma, or cardiovascular disorders; had undergone major nasal or otologic surgery; had an abnormal urinalysis, complete blood count, or blood enzymes; were pregnant or currently lactating; tested seropositive for HIV; or took regular medication (except birth control). Baseline immunity to the challenge virus (viral-specific antibody titers), demographics, weight, and height were also assessed at screening. We maximized the rate of infection by considering only those participants with low levels of immunity to the virus (viral-specific antibody titers ≤ 4) at the medical screening eligible for the study.

At study baseline, volunteers who met the inclusion criteria completed a questionnaire assessing perceived availability of social support and were interviewed by telephone for 14 consecutive evenings. Interviews included queries about social activities, interpersonal tension or conflicts, and whether participants were hugged on each interview day.

One to 3 weeks following completion of the interviews, participants were quarantined in separate rooms on an isolated floor in a local hotel. All procedures conducted while participants were in quarantine were identical for both studies. Blood was drawn for assessment of baseline antibody levels during the 5-day period before viral exposure. During the first quarantine day and prior to viral exposure, participants in both studies completed personality questionnaires; received an examination of the ears, nose, and throat; and provided a nasal-wash specimen that was cultured for existing viral infection. Baseline objective measures of congestion (nasal mucociliary clearance time) and nasal mucus production were assessed. Five volunteers (not included in the total of 406) were excluded from study participation at this point because they reported having a cold or symptoms of a cold, or retroactively because a viral pathogen was later isolated from the nasal wash.

After collection of baseline data, we gave each participant nasal drops containing approximately 150 tissue culture infectious dose$_{50}$ (TCID$_{50}$) of rhinovirus (RV) 39 or 10^5 TCID$_{50}$ of influenza A/Texas/36/91, both viruses that cause common coldlike illnesses. We used two viruses in order to establish the generalizability of observed associations. The quarantine continued for 5 (RV39) or 6 (influenza) days. On each day, participants were assessed for nasal mucociliary clearance and nasal mucus production, and nasal-wash samples were collected for virus culture. Approximately 28 days after virus exposure, blood was collected to assay for level of antibody to the challenge virus. The on-site investigators were blind to all interview, questionnaire, and biological measures.

Measures

Standard control variables. Eight control variables (covariates in analyses) were collected at screening: age (continuous), sex (male, female), race (white, other), virus (RV, influenza), season of the year (spring, summer, fall, winter), body mass index (BMI; weight in kilograms/height in meters^2), marital status (married or living in a marital-like relationship vs. all other types of relationship, i.e., separated/divorced, widowed, never married), and educational attainment (high school or less, some college, ≥ 2 years with degree or certificate, bachelor's degree or greater). The remaining two control variables were study (1, 2), and viral-specific immunity (the preexposure level of specific antibody to the challenge virus). Although only volunteers with antibody titers of 4 or less were invited to participate at screening (8–12 weeks before challenge), some evidenced titers greater than 4 when preexposure levels were reassessed (0–5 days before challenge; see Fig. 2). The apparent elevation in antibody levels could be due to assay error or natural exposure to the virus in the interim. Therefore, we included a control variable indicating whether participants' level of antibody to the challenge virus as assessed just prior to viral exposure had titers less than 4 or greater than or equal to 4.

Perceived social support. Support was assessed using the 12-item version of the Interpersonal Support Evaluation List (ISEL; Cohen, Mermelstein, Kamarck, & Hoberman, 1985; http://www.psy.cmu.edu/~scohen/ISEL12.html). The ISEL-12 contains items drawn from three of the four subscales included in the original scale, with each subscale represented by the four highest-loading component items. The three represented subscales assess the availability of persons with whom the respondent can talk about his or her problems, persons with whom the respondent can spend time doing things, and persons who would provide the respondent with material aid if needed. Participants responded to each item on a scale ranging from 0, *definitely false*, to 4, *definitely true*. Total perceived-support scores were derived by summing the 12 items. Because positive and negative items on the scale were counterbalanced, negatively stated items (indicating low support) were reverse-scored. The internal reliability (Cronbach's α) for the scale was .82.

Interactions, conflicts, and hugs. Telephone interviews were conducted on 14 consecutive evenings. During each interview, participants were asked whether they engaged in each of five types of activities with other persons during the last 24 hr (they were also asked two open-ended questions about any activities not included in the five categories). Activity categories were eating (e.g., having a meal, dessert, or a cup of coffee), leisure activities at home (e.g., watching TV, reading, playing a game), leisure activities away from home (e.g., going to a movie, to a sporting event, or for a walk or hike), work around the house (e.g., yard work, home improvements, cleaning, laundry, paperwork), and family or personal errands (e.g., grocery shopping, going to the doctor, taking the kids somewhere). From these data, we calculated the average number of interactions with other people per day and the percentage of days during which participants interacted with other people (any activity). At the end of every interview, participants were also asked whether they were involved in any interpersonal tension or conflict during the day (yes/no) and whether anyone had hugged them that day (yes/no).

Personality. In Study 1, extraversion, agreeableness, and neuroticism were assessed using items derived from Goldberg's Adjective Scale (Cohen, Doyle, Skoner, Rabin, & Gwaltney, 1997; Goldberg, 1992). Each personality dimension was represented by the five highest-loading items for the relevant factor. Internal reliabilities for each scale were .74 for extraversion and agreeableness and .80 for neuroticism. In Study 2, these same personality dimensions were measured using the relevant 10-item Big Five subscales of the International Personality Item Pool (Goldberg et al., 2006), with internal reliabilities of .88 for extraversion and neuroticism and .85 for agreeableness. To establish equivalency across the two studies, we computed standardized scores (z scores) for each subscale prior to inclusion in the analysis.

Disease outcomes

Infection. Infection is the replication of the virus. When upper respiratory viruses replicate, they can be found in nasal-secretion samples. Samples collected daily in a saline wash of the nose were frozen and later cultured for the challenge virus using standard techniques (Dowdle, Kendal, & Noble, 1979; Gwaltney, Colonno, Hamparian, & Turner, 1989). Because the immune system responds to infection by producing antibody to the virus, increases in viral-specific antibody level provide an indirect marker of infection. Hence, we compared virus-specific antibody levels measured in serum collected before and 28 days after exposure using a criterion ($\geq$ 4-fold increase) that has been validated by virologists as an indicator of infection (Dowdle et al., 1979; Gwaltney et al., 1989). In sum, infection was operationally defined as recovery of the challenge virus on any of the 5 (RV39) or 6 (influenza) postchallenge days or a 4-fold or greater rise in virus-specific serum-neutralizing antibody titer (before exposure to 28 days after exposure; Cohen et al., 1997).

Signs of illness. We assessed two objective markers of upper respiratory illness: nasal mucus production and nasal mucociliary clearance function. Daily mucus production was assessed by collecting used tissues in sealed plastic bags (Doyle, McBride, Swarts, Hayden, & Gwaltney, 1988). The bags were weighed, and the weight of the tissues and bags was subtracted to determine the weight of mucus produced. Clearance function refers to the effectiveness of nasal cilia in clearing mucus from the nasal passage toward the throat. Ineffective clearance function is subjectively experienced as congestion. Clearance function was assessed by determining the time required for a saccharin-dyed solution administered into the anterior nose to be tasted by the participant (Doyle et al., 1988).

To create baseline-adjusted daily scores for each measure, we subtracted the appropriate baseline score (from the day before the challenge virus was administered) from each of the 5 (RV39) or 6 (influenza) postchallenge daily scores (Cohen et al., 1997). Negative adjusted scores were reassigned a value of 0. Average daily mucus-production and nasal-clearance scores were calculated by summing the respective adjusted daily scores for each measure over all postchallenge days and then dividing by the total number of days. Total mucus-weight scores were created by multiplying the average daily scores by 5 to equate the 5-day (RV) and 6-day (influenza) sampling periods.

Clinical illness. Participants were determined to have developed a clinical cold if they both were infected with the challenge virus and met either of the following criteria: total baseline-adjusted mucus weight of 10 g or more, or average (across all postchallenge days) baseline-adjusted nasal mucociliary clearance time of 7 min or longer (Cohen et al., 1997).

Data analysis

Separate multivariable logistic regression models were used to examine whether perceived social support and being hugged, respectively, attenuated the association of daily interpersonal tension with the dichotomous outcome infection. Analogous multivariable linear regression models were run to examine the buffering effects of social support and hugging, respectively, on the association of daily tension with each of the continuous measures of illness expression (nasal mucociliary clearance function and nasal mucus production) among infected persons. Finally, logistic models were also used to examine clinical illness.

In both the logistic and linear models, we tested for main effects of social tension and either social support or hugs. Moderation models included the main effects of tension and either social support or hugs (all centered at their respective means), as well as the cross-product of the relevant centered variables (i.e., Tension × Support or Tension × Hugs). If both cross-product terms emerged as significant predictors of a given outcome, an additional model was run that examined both effects simultaneously—that is, one that included all main effects (i.e., daily tension, social support, and daily hugs) and the two cross-product terms (Tension × Support and Tension × Hugs).

All models included the 10 standard covariates (age, sex, race, marital status, BMI, prechallenge antibody level, virus, season of the year, education, and study). In cases of significant associations, results from a model without the standard covariates are also reported. To rule out personality as a potential third-factor explanation for observed effects, we tested an additional set of models that included controls for relevant personality variables and their interactions with daily tension in addition to the standard covariates.

Odds ratios (ORs) and 95% confidence intervals (CIs) are reported for main effects from logistic regression models. For interactions, unstandardized regression coefficients (*b*s) and 95% CIs are reported, and chi-square (χ^2) values are provided to indicate the improvement in prediction associated with the addition of the interaction term to the model. For the linear models, we report standardized coefficients (βs) with 95% CIs, as well as change in the squared multiple-correlation coefficient associated with adding the predictor to the model (ΔR^2). For all analyses, we report *p* values, and all tests were two-tailed.

Because it is possible that the effects of the predictor variables differed depending on whether participants were infected with RV or influenza virus, we ran an additional set of analyses that incorporated virus type as an additional moderator. Specifically, we examined the three-way interactions of Tension × Support × Virus and Tension × Hugs × Virus in predicting each of the four study outcomes. These models also included the main effects, the component two-way interactions, and the standard covariates.

Results

Descriptive data

Seventy-eight percent (n = 315) of participants became infected with the challenge virus, and 31.4% (n = 127) met criteria for clinical illness. The median total adjusted mucus production was 2.90 g (range: 0.00–345.00), and the median average adjusted nasal clearance time was 2.60 min (range: 0.00–19.60). Among infected participants only, the corresponding values were 3.77 g (range: 0.00–345.00) and 2.92 min (range: 0.00–19.60), respectively. On average, participants completed 13.93 (95% CI = [13.17, 14.69]) daily interviews, with 97.5% (n = 394) completing all 14 interviews. Participants were more likely to be hugged than to experience interpersonal tension or conflict, $t(403) = 28.34$, $p < .001$; hugs were reported on a median of 67.86% (range: 0–100%) of interview days, and tension or conflict was reported on a median of 7.14% (range: 0–85.71%) of days. The median ISEL score was 42.00 (range: 18.00–48.00). Higher levels of perceived support were associated with more-frequent hugging ($r = .37$, $p < .001$) but were unrelated to frequency of experiencing tension or conflict ($r = -.01$, $p = .86$).

Associations of covariates with outcomes

Ten separate models, in each of which only a single variable was entered, were fit to estimate the association of each of the standard covariates with each outcome. Six of the standard covariates were associated with at least one outcome. Having a prechallenge virus-specific antibody titer of 4 or greater was associated with reduced odds of becoming infected (OR = 0.30, 95% CI = [0.18, 0.48], p = .001, n = 404) and of developing a cold (OR = 0.33, 95% CI = [0.20, 0.56], p = .001, n = 403), decreased mucus weights (b = −0.18, 95% CI = [−0.34, −0.02], p = .024, n = 315), and more-rapid nasal clearance (b = −0.12, 95% CI = [−0.21, −0.03], p = .012, n = 315). Greater age was related to higher odds of developing a cold (OR = 1.03, 95% CI = [1.01, 1.05], p = .005, n = 403) and greater mucus weights (b = 0.01, 95% CI = [0.003, 0.02], p = .003, n = 315), as was higher BMI (cold: OR = 1.03, 95% CI = [1.00, 1.06], p = .068; mucus weights: b = 0.01, 95% CI = [0.00, 0.02], p = .052).

Exposure to the challenge virus during the winter months was associated with reduced risk of infection (OR = 0.43, 95% CI = [0.24, 0.77], p = .004), whereas exposure during the spring was associated with reduced risk of developing a cold (OR = 0.63, 95% CI = [0.41, 0.97], p = .037) and reduced nasal clearance times (b = −0.07, 95% CI = [−0.15, 0.01], p = .085). Participants exposed to the influenza virus were less likely to become infected than those exposed to RV39 (OR = 0.27, 95% CI = [0.13, 0.53], p = .001), and women had increased mucus weights relative to men (b = 0.23, 95% CI = [0.09, 0.37], p = .001).

Risk for infection

Tension and perceived social support. When examined in the same model, there was no main effect for either the percentage of days with tension (OR = 1.74, 95% CI = [0.27, 10.93], p = .56) or perceived social support (OR = 0.99, 95% CI = [0.95, 1.04], p = .70) in predicting infection. However, social support moderated the association between the percentage of days with tension and infection risk (Tension × Social Support interaction: b = −0.40, 95% CI = [−0.79, −0.003], p = .048), $\chi^2(1)$ = 4.72, p = .03 (without standard covariates: b = −0.43, 95% CI = [−0.79, −0.07], p = .019). Consistent with the buffering hypothesis, results showed that experiencing more-frequent tension was associated with increased risk of infection among participants with lower levels of social support, whereas among those with higher support, tension was unrelated to infection. The interaction is shown in Figure 3, in which the adjusted predicted values

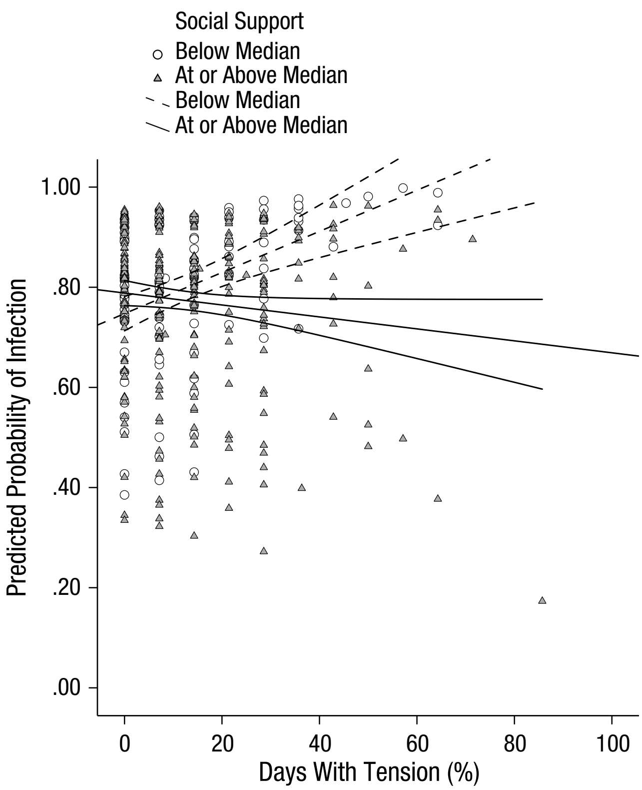

Fig. 3. Scatter plot showing the adjusted predicted probability of infection as a function of the percentage of days during which participants experienced interpersonal tension and participants' level of perceived social support. High and low groups were created by splitting the sample at the median social-support score (42.00). Curved lines indicate 95% confidence intervals.

generated from the regression equation (ordinate) are plotted against the percentage of days with tension (abscissa). For purposes of illustration (the analysis used continuous data), the sample was split at the median score for social support (42.00) to create high and low groups. When testing the simple slopes on the basis of this median split, there was a trend (p = .066) for increasing infection risk with increasing tension among participants with low support, but no association among those with high support (p = .32).

Tension and hugs. To determine whether interpersonal touch also has a buffering effect on the association between tension and risk for infection, we conducted the analyses a second time, substituting the percentage of days with hugs for perceived social support. Again, there was no main effect of the percentage of days with tension on infection risk (OR = 2.08, 95% CI = [0.32, 13.45], p = .44). However, the percentage of days with hugs was inversely related to infection risk such that being hugged more frequently was associated with a lower risk of infection (OR = 0.39, 95% CI = [0.16, 0.96], p = .04; without standard covariates: OR = 0.36, 95% CI = [0.17, 0.77], p = .009).

Including the Tension × Hugs cross-product term in the model revealed a moderating effect of hug frequency on the association of tension frequency with infection risk (Tension × Hugs interaction: b = −12.31, 95% CI = [−20.94, −3.69], p = .005; $\chi^2(1)$ = 9.35, p = .002; without standard covariates: b = −10.06, 95% CI = [−17.49, −2.63], p = .008). As in the Tension × Support model, experiencing more days with tension was associated with increased risk of infection among participants who were hugged on fewer days relative to those who were hugged more frequently. Figure 4 illustrates the nature of the interaction. Groups high and low in hugs were created by splitting the sample at the median for the percentage of days with hugs (67.9%). The adjusted predicted values were generated from the regression equation using the continuous variables. When testing the simple slopes on the basis of the median split of hugs, infection risk increased with increasing tension (p = .008) among those in the low group but was unrelated to tension in the high group (p = .17).

Controlling for frequency of social interaction. Frequencies of both daily tension and hugging are intrinsically confounded with the frequency of social interaction. People cannot experience interpersonal tension or receive a hug on any given day unless that day included some social interaction. Moreover, engaging in more social interactions per day would increase the probability of conflicts and hugs. Here, both the percentage of days with hugs and the percentage of days with tension increased as the number of days that involved at least one social interaction increased (r = .42 and r = .21, respectively, p < .001) and as the average number of social interactions per day increased (r = .53 and r = .32, respectively, p < .001). Hence, we refit the relevant model making the following adjustments. We substituted into the model terms that express days with tension and days with hugs as proportions of social-interaction days rather than as proportions of total interviews. To control for daily social-interaction frequency, we included as covariates the average number of interactions per day and the Tension × Average Interactions per Day cross-product term.

Using this adjusted model, we found that the percentage of days with hugs continued to moderate the association between the percentage of days with tension and infection risk (Tension × Hug interaction: b = −9.47, 95% CI = [−16.82, −2.13], p = .010), $\chi^2(1)$ = 7.39, p = .007, and the form of the interaction was such that more-frequent tension was associated with greater risk of infection when hugs were received infrequently but not when received frequently. Although the adjustments made to the model

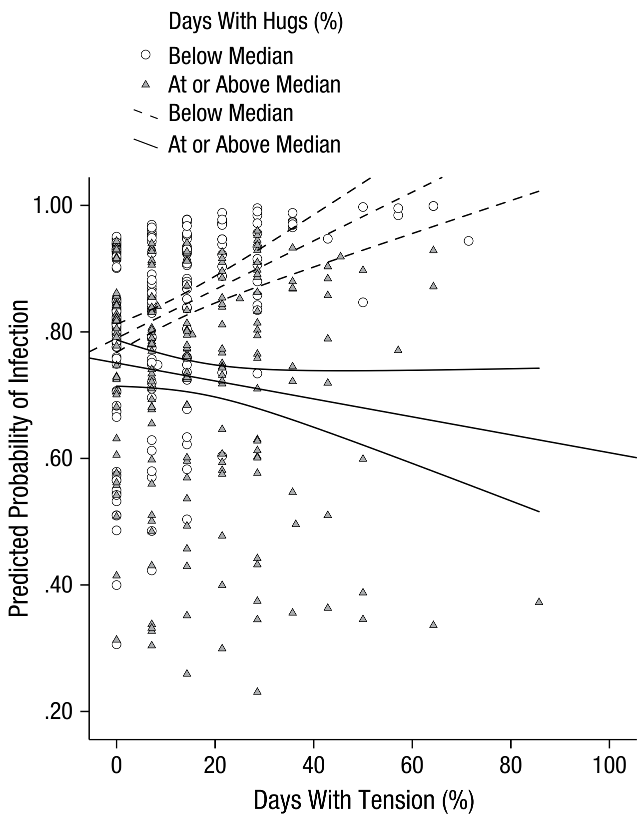

Fig. 4. Scatter plot showing the adjusted predicted probability of infection as a function of the percentage of days during which participants experienced interpersonal tension and the frequency with which participants were hugged. High and low groups were created by splitting the sample at the median for the percentage of days with hugs (67.9%). Curved lines indicate 95% confidence intervals.

did not affect the moderating effect of the percentage of days with hugs on the association between the percentage of days with tension and infection risk, their incorporation did result in the loss of the main effect of hugs on infection (OR = 0.57, 95% CI = [0.23, 1.38], p = .21).

Is the buffering effect of hugs responsible for support buffering tension? To determine the overlap of the respective moderating effects of perceived support and hug frequency on the association of tension frequency with infection, we entered both relevant cross-product terms into the same model along with the standard covariates and the main effects of the percentage of days with tension, the percentage of days with hugs, and perceived social support. When the two interactions were included in the model predicting infection, there was a 32% reduction in the regression coefficient for the Percentage of Days With Tension × Perceived Support interaction, as well as a loss of statistical significance (b = −0.29, 95% CI = [−0.68, 0.10], p = .15). Moreover, the addition of the Tension × Support cross-product did not improve model fit, $\chi^2(1)$ = 2.35, p = .125. By comparison, the moderating effect of the percentage of days with hugs remained largely unchanged (b = −11.08, 95% CI = [−20.07, −2.09], p = .016), and addition of the Tension × Hug interaction term to a model already including the interaction with social support significantly improved model prediction, $\chi^2(1)$ = 6.44, p = .011.

Do buffering hugs occur on tension days? A possible explanation for the buffering effects of hugs is that participants engaged in hugs with persons involved in the tension or conflict as a means of resolving that conflict or at least its emotional effects. As data were not collected on the sources of tension or conflict or on who provided hugs, we could not test this hypothesis directly. However, we could address the question indirectly by first determining whether hugs were received more frequently on days with tension or conflicts than on nontension days and, second, whether hugs received on tension relative to nontension days were more likely to buffer the association of tension with infection.

Among participants who reported tension or conflict during at least one interview (n = 279), comparison of tension and nontension days revealed only a marginal difference in the frequency of being hugged (z = −1.63, p = .103), with hugs occurring on 69.1% (95% CI = [−8.5, 146.7]) of tension days versus 66.9% (95% CI = [3.2, 130.6]) of nontension days. In regard to the buffering effect, receiving hugs on a greater proportion of nontension days was associated with a lower risk of infection for participants with a high percentage of conflicts (OR = 0.19, 95% CI = [0.06, 0.64], p = .007, n = 279). Receiving hugs on a greater proportion of tension days also was related to lower infection risk, but the association failed to meet the .05 significance criterion (OR = 0.54, 95% CI = [0.23, 1.30], p = .170, n = 279).

Signs of illness among infected participants

An independent set of analyses was conducted to assess whether tension, social support, and hugging could predict which of the participants who were infected by the experimental virus (315 of the original 404) developed objective signs of illness.

Tension and perceived social support. We examined whether the percentage of days with tension, perceived social support, and their interaction were associated with the severity of two objective signs of illness—nasal-mucus weights and nasal mucociliary clearance time. More social support was associated with more-rapid nasal clearance (b = −0.01, 95% CI = [−0.02, 0.00], β = −0.12, p = .046, ΔR^2 = .013; without standard covariates:

$b = -0.01$, 95% CI = [−0.02, −0.001], $\beta = -0.12$, $p = .038$, $\Delta R^2 = .014$) but was unrelated to mucus production ($b = 0.01$, 95% CI = [−0.01, 0.02], $\beta = 0.05$, $p = .39$, $\Delta R^2 = .002$). By contrast, the percentage of days with tension was unrelated to nasal clearance ($b = 0.04$, 95% CI = [−0.25, 0.33], $\beta = 0.02$, $p = .78$, $\Delta R^2 = .0003$) but was marginally associated with increased mucus production ($b = 0.34$, 95% CI = [−0.15, 0.83], $\beta = 0.08$, $p = .17$, $\Delta R^2 = .007$; without standard covariates: $b = 0.46$, 95% CI = [−0.02, 0.93], $\beta = 0.11$, $p = .059$, $\Delta R^2 = .012$). Perceived support did not interact with the percentage of days with tension to predict either outcome ($p > .13$).

Tension and hugs. Analogous to the findings for social support, results showed that more-frequent hugs were associated with more-efficient nasal clearance ($b = -0.14$, 95% CI = [−0.28, −0.004], $\beta = -0.13$, $p = .044$, $\Delta R^2 = .013$; without standard covariates: $b = -0.13$, 95% CI = [−0.24, −0.01], $\beta = -0.12$, $p = .04$, $\Delta R^2 = .013$) but were unrelated to mucus production ($b = 0.02$, 95% CI = [−0.20, 0.25], $\beta = 0.01$, $p = .83$, $\Delta R^2 = .0004$). There was no interaction between the percentage of days with tension and the percentage of days with hugs for either illness outcome ($p > .26$).

To determine whether the association between being hugged more frequently and shorter nasal clearance time overlapped with the effect of perceived support, we entered both variables simultaneously into a single model that included the standard covariates. Neither variable emerged as an independent correlate of nasal clearance (percentage of days with hugs: $b = -0.10$, 95% CI = [−0.24, 0.04], $\beta = -0.09$, $p = .16$, $\Delta R^2 = .006$; perceived support: $b = -0.01$, 95% CI = [−0.01, 0.002], $p = .13$, $\Delta R^2 = .007$). Further, subsequent addition of either the percentage of days with hugs or social support to a model examining the other variable as the predictor resulted in a 25% reduction in the association of the predictor with nasal clearance time.

Clinical illness

Colds were evaluated in analyses with all participants. Neither the percentage of days with tension (OR = 1.23, 95% CI = [0.26, 5.81], $p = .79$) nor perceived social support (OR = 1.00, 95% CI = [0.96, 1.04], $p = .98$) was associated with risk for clinical illness, and the Tension × Support interaction indicated no moderating effect ($b = 0.15$, $SE = 0.13$, $p = .26$), $\chi^2(1) = 1.30$, $p = .26$. Likewise, the percentage of days with hugs was unrelated to illness risk (OR = 1.02, 95% CI = [0.48, 2.16], $p = .96$), and the Tension × Hugs interaction was not significant ($b = -2.53$, $SE = 2.55$, $p = .32$), $\chi^2(1) = 0.98$, $p = .32$.

Controlling for personality

An alternative explanation for the findings reported so far is that perceptions of social support and the frequency of being hugged or experiencing interpersonal tension were influenced largely by relevant personality characteristics (i.e., extraversion, agreeableness, and neuroticism) and that it is between-person differences in these traits that account for the associations of social support, tension, and hugs with the examined outcomes. Perceiving more social support was correlated with higher extraversion ($r = .24$, $p < .001$) and agreeableness ($r = .22$, $p < .001$) and lower neuroticism ($r = -.24$, $p < .001$). Reporting more-frequent hugs was correlated with higher extraversion ($r = .11$, $p = .021$) and agreeableness ($r = .21$, $p < .001$), whereas reporting more-frequent tension was related to higher extraversion ($r = .12$, $p = .013$) and neuroticism ($r = .23$, $p < .001$).

In regard to main effects, including extraversion, agreeableness, and neuroticism as additional controls along with the standard covariates and the percentage of days with tension did not affect the association between the percentage of days with hugs and decreased risk of infection (OR = 0.34, 95% CI = [0.13, 0.87], $p = .025$). Among infected participants ($n = 315$), inclusion of the three personality characteristics similarly did not affect the association between either perceived social support ($b = -0.01$, 95% CI = [−0.02, −0.002], $\beta = -0.16$, $p < .014$, $\Delta R^2 = .019$) or the percentage of days with hugs ($b = -0.16$, 95% CI = [−0.30, −0.02], $\beta = -0.15$, $p = .027$, $\Delta R^2 = .015$) and more-rapid nasal clearance.

In regard to the moderating effect of perceived social support on the association between the percentage of days with tension and infection, including additional controls for agreeableness, extraversion, neuroticism, and their respective interactions with tension had little impact on the size of the interaction effect of the percentage of days with tension and perceived support, ($b = -0.37$, 95% CI = [−0.77, 0.03], $p = .074$), $\chi^2(1) = 3.72$, $p = .054$. Similarly, in the analogous model that substituted the percentage of days with hugs for perceived support, including the additional controls for personality did not have an appreciable effect on the size of the interaction ($b = -7.46$, 95% CI = [−14.53, −0.39], $p = .039$), $\chi^2(1) = 4.57$, $p = .033$.

Pathogen effects

To determine whether the reported associations were equivalent across viruses, we tested the Hugs × Virus (influenza or RV), Perceived Support × Virus, Tension × Perceived Support × Virus, and Tension × Hugs × Virus interactions. None were significant (*p*s > .13).

Discussion

Interpersonal stressors have been found to predict an increased likelihood of developing clinical illness in viral-challenge studies. Disease risk in these studies has been attributed to stress influences on the susceptibility to infection and the development of illness signs once infected (e.g., Cohen et al., 1999; Cohen et al., 1991). In the present research, we found that interpersonal stress, social support, and hugs were associated with both infection and illness signs, but not with developing a clinical illness. Lack of a clinical effect could be attributable to insufficient power or to social support and hugs playing different roles in the component disease processes (stress-buffering for infection, direct effect for signs of illness). That said, infection and illness signs are both necessary components of clinical disease and provide valuable information about how people's bodies respond to infectious challenges. Immune processes involved in preventing infection (e.g., blocking viral entry into host cells via binding of antibody or killing host cells that have been infected) and in producing signs of illness (e.g., release of proinflammatory proteins or virus-induced structural damage) have important implications for understanding the roles of stress, support, and hugs in response to other viral pathogens.

In predicting infection, we found evidence consistent with the social-support stress-buffering hypothesis (Cohen & Wills, 1985; House, 1981). For participants perceiving low social support, more-frequent interpersonal tension and conflict was associated with a greater probability of infection subsequent to viral exposure. In contrast, among participants perceiving greater support, the frequency of tension and conflict was unrelated to infection susceptibility. Virtually identical results emerged when hugs were examined as the potential stress buffer. Moreover, the Tension × Hugs interaction explained 32% of the buffering effect of support, evidence consistent with close contact acting as a behavioral mediator of perceived support.

These data are consistent with the hypothesis that nonsexual physical touch, such as hugging, is a means of conveying empathy, caring, and reassurance (e.g., Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006; Holt-Lunstad et al., 2008; Reis & Patrick, 1996) and that this implicit communication of affection and concern is an important contributor to the protective influence of perceived support against the pathogenic effects of stress. These data are also consistent with a small literature providing evidence that social support buffers the effects of stress on physical health (Falk et al., 1992; Rosengren et al., 1993), as well as with laboratory studies showing that physical contact with a close other person reduces the effects of stress on biological markers thought to be precursors of disease (Ditzen et al., 2007; Grewen et al., 2003). Finally, these data are also consistent with findings from comparative research wherein cynomolgus macaques that displayed more affiliative behaviors (touch, closeness, grooming) were protected from social-stress-induced suppression of cellular immunity (Cohen, Kaplan, Cunnick, Manuck, & Rabin, 1992).

A possible explanation for the buffering effect of being hugged is that hugs might be exchanged between individuals involved in a situation involving tension and conflict either as a means of resolving that conflict or as a counter to associated emotional aftereffects. In predicting infection, we found that hugs on nontension days were at least as important as hugs reported on tension days, which suggests that the buffering effects of hugging were not limited to hugs given as an immediate (same-day) response to tension and conflict. These findings suggest that people who regularly receive hugs are more protected than those who do not, although we cannot discount the possibility that those who are hugged more frequently also are more likely to use hugs to resolve conflicts.

In contrast to the stress-buffering effect we observed when predicting infection, our findings revealed main effects of social support and of hugs when predicting objective signs of illness. Specifically, participants perceiving greater support and those reporting more-frequent hugs showed more-rapid nasal clearance, that is, less indication of illness. Neither support nor hugs interacted with tension in this case. The lack of a buffering effect may be attributable to participants who were hugged most frequently not having been infected (and hence not included in these analyses) or to the decrease in sample size and hence power when we examined only infected subjects. Alternatively, support and hugging may directly affect the expression of illness signs through either physiological or behavioral pathways. Notably, these analyses examined continuous illness outcomes. Similar analyses (not reported here) substituted dichotomous illness outcomes based on the clinical thresholds. These analyses revealed that neither support, hugs, nor their interaction with tension predicted whether participants met the clinical thresholds.

No significant associations emerged when total mucus weight, the other disease indicator, was examined as an outcome. This inconsistency might be explained by mucus production and nasal mucociliary clearance function being driven by different physiological mechanisms. Whereas mucus production is thought to be controlled by biochemical processes (Cohen et al., 1999), impaired nasal clearance is thought to be influenced by microstructural damage to the nasal epithelium (Carson, Collier, & Hu, 1985).

A seldom-tested explanation for the effectiveness of perceived social support and touch in ameliorating the detrimental effects of stress is that it may be attributable to correlated personality characteristics. Here, we controlled for extraversion, agreeableness, and neuroticism, all traits that have been associated with both social-interaction styles and disease risk, and found that none of them (alone or together) could explain any of the effects we reported.

The apparent protective effect of hugs may be attributable to the physical contact itself or to hugging being a behavioral indicator of support and intimacy. Either way, people who receive more hugs are somewhat more protected from infection and illness-related symptoms. The overall positive associations with hugs are consistent with experimental research wherein married couples who were trained to increase warm touch showed higher levels of salivary oxytocin and lower levels of salivary alpha amylase and blood pressure (Holt-Lundstad et al., 2008). However, the warm-touch study did not address whether touch had an overall positive effect or was operating only when individuals were being challenged by stressors, interpersonal or otherwise.

It is also possible that support and hugs are protective because both are markers of physical contact, and having a history of physical contact may have led to previous exposure to viral pathogens that, in turn, provided immunity in the face of further exposures. We addressed this issue by enrolling only volunteers with low levels of immunity to the challenge virus (viral-specific antibody) in addition to statistically controlling for preexisting levels of viral-specific antibody assessed just prior to viral exposure.

A limitation of this study is that we do not know with whom participants engaged in conflict or by whom they were hugged. This information could provide insight into potential explanatory mechanisms. The correlational nature of this work limits causal inference. However, the prospective viral-challenge paradigm eliminates reverse causation as an explanation. Clearly, neither infection with the challenge virus nor subsequent illness expression could have caused interpersonal tension, social support, or hugs. Finally, the design of the viral challenge was such that the likelihood of infection would be maximized. Thus, it is possible that participants who resisted infection despite the favorable conditions may have been distinguished in some important way from those who did become infected. Our incorporation of multiple controls for potential third-factor explanations, however, substantially reduces this possibility.

Viewed in light of the experimental studies demonstrating a buffering effect of interpersonal touch on physiologic response to laboratory stress (Ditzen et al., 2007; Grewen et al., 2003; Master et al., 2009), and the intervention demonstrating the impact of touch on sympathetic activation (Holt-Lundstad et al., 2008), these data suggest the potential importance of touch in health-related outcomes. Moreover, that the buffering effect of hugs could explain much of the attenuating effect of social support suggests that hugging is a behavior that may be manipulated to provide the beneficial effects associated with support.

Author Contributions

S. Cohen developed the study concept. All authors contributed to the study design. W. J. Doyle supervised the viral-challenge trial, R. B. Turner conducted all the rhinovirus assays, and D. Janicki-Deverts and S. Cohen conducted the statistical analyses and interpreted the results. S. Cohen and D. Janicki-Deverts were primarily responsible for writing the manuscript, with all remaining authors providing critical revisions. All authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Open Practices

All data have been made publicly available via Dryad and can be accessed at http://datadryad.org/resource/doi:10.5061/dryad.g7b40. The complete Open Practices Disclosure for this article can be found at http://pss.sagepub.com/content/by/supplemental-data. This article has received badges for Open Data. More information about the Open Practices badges can be found at https://osf.io/tvyxz/wiki/view/ and http://pss.sagepub.com/content/25/1/3.full.

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