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Is flourishing good for the heart? Relationships between positive psychology characteristics and cardiorespiratory health

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Título: ¿Es la salud psicológica buena para el corazón? Relación entre características psicológicas positivas y variables cardiorrespiratorias.
Resumen: *Introducción*: Muchos estudios han demostrado que las características psicológicas positivas son factores de protección contra las enfermedades cardiovasculares. El objetivo de este estudio es ampliar los datos conocidos acerca de las relaciones entre las cualidades positivas y los parámetros cardiorrespiratorios, incluida la rigidez arterial.
Método: Las hipótesis fueron contrastadas transversalmente en una muestra clínica de pacientes con enfermedades cardiovasculares y otra muestra de pacientes sanos. La satisfacción en la vida, el bienestar psicológico, el optimismo, el sentido de la vida y el sentimiento de coherencia fueron considerados indicadores psicológicos, mientras que las variables fisiológicas tenidas en cuenta fueron la presión arterial periférica y central, la rigidez arterial, el ciclo cardiaco y la función respiratoria. La relación entre las variables dependientes e independientes, ajustadas por sexo, edad y nivel educativo se analizó mediante un modelo lineal. También se examinaron las relaciones no lineales entre las variables dependientes e independientes.
Resultados: La mayoría de las asociaciones estudiadas no fueron significativas para ninguna de las dos muestras, aunque con algunas excepciones notables: la satisfacción en la vida se relacionó con una tensión arterial sistólica periférica menor, así como con una presión arterial media más baja en la muestra clínica. El sentido de la coherencia se asoció positivamente al volumen respiratorio forzado. En la muestra sana, el índice aórtico y la presión arterial sistólica presentaron una asociación negativa con el optimismo; sin embargo, utilizando la corrección de Bonferroni, ninguna de las relaciones lineales o no lineales resultaron significativas en las muestras.
Conclusiones: estudios futuros deberán determinar si estos hallazgos derivan de las características culturales de estas muestras en concreto, o si los mediadores entre la salud psicológica y la salud cardiorrespiratoria deberían ser buscados más allá de las variables incluidas en este estudio.
Palabras clave: psicología positiva, encontrarse bien, indicadores cardiovasculares, rigidez arterial, función respiratoria.

Abstract: The purpose of this study was to provide further data on the relationships between positive psychology constructs and cardiorespiratory parameters including arterial stiffness indicators. Hypotheses were tested cross-sectionally on a sample of patients with cardiovascular disease and on a healthy sample. Life satisfaction, psychological well-being, optimism, meaning in life, and sense of coherence were included as psychological indicators, while peripheral and central blood pressure, arterial stiffness, and heart cycle and respiratory function parameters were used as physiological variables. Most of the associations examined were not significant in either sample, with some notable exceptions (the direction of these linear relationships was in accordance with our expectations). Satisfaction with life was related to lower peripheral systolic and mean arterial blood pressure in the clinical sample. Further, sense of coherence was positively associated with forced expiratory volume. In the healthy sample, the augmentation indexes and aortic systolic blood pressure were negatively associated with optimism. However, none of the linear and non-linear relationships proved to be significant in either of the samples when using the Bonferroni correction. Further research should determine whether the present findings derive from the cultural characteristics of our samples or whether the mediators between flourishing and cardiorespiratory health should be sought among other variables than the ones included in the present investigation.
Key words: positive psychology; well-being; cardiovascular indicators; arterial stiffness; lung functions.

Introduction

Positive psychology deals with human strengths and virtues (Sheldon & King, 2001) including positive subjective experiences at the subjective level (e.g., happiness or optimism), positive personality traits on the personal level (e.g., forgiveness or wisdom), and civic virtues at the community level (e.g., responsibility or tolerance) (Seligman & Csikszentmihalyi, 2000). When conceptualizing positive psychological phenomena, related constructs are often categorized as hedonic or eudaimonic characteristics. While the first refers to well-being in terms of pleasure attainment and pain avoidance, the latter focuses on life meaning and self-realization and defines well-being in terms of the degree to which a person fulfills his or her potential (Ryan & Deci, 2001). There are also positive attributes that are not easily classified according to these two categories, for example, optimism, which is the most widely investigated positive psychological construct concerning cardiac health. Although the relevance of positive psychology in health sciences has been more and more widely accepted, a recent content analysis (Schmidt, Raque-Bogdan, Piontkowski, & Schaefer, 2011) showed that many articles in health science journals merely mention positive constructs and only a small percentage had an overt focus on these phenomena.

Nevertheless, previously performed empirical studies, conducted since the beginning of the positive psychology movement, have shown that positive constructs are not only associated with a larger likelihood of psychological flourish-

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ing but that they have important implications for physical health as well. For instance, a stronger sense of coherence and meaning in life were found to be associated with better self-rated health and physical health conditions (Eriksson & Lindström, 2006; Krause, 2004). Other studies demonstrated that individuals with stronger dispositional optimism had better immune functions, as measured by the number of helper T cells, and higher natural killer cell cytotoxicity (Segerstrom, Taylor, Kemeny, & Fahey, 1998).

Several studies also investigated the relationships between positive psychological characteristics and cardiovascular morbidity, the leading cause of death in the world (World Health Organization, 2008). The results showed that positive psychological attributes were associated with reduced risk of coronary heart disease and cardiovascular mortality especially in older populations (Boehm & Kubzansky, 2012; Chida & Steptoe, 2008; DuBois et al., 2012). The examined constructs extended from satisfaction with life (Boehm, Peterson, Kivimaki, & Kubzansky, 2011b) to sense of coherence (Surtees, Wainwright, Luben, Khaw, & Day, 2003), through perceived meaning in life (Seki, 2001) or dispositional optimism (Giltay, Geleijnse, Zitman, Hoekstra, & Schouten, 2004; Tindle et al., 2009). The investigated cultures were also diverse including such distant regions of the world as Japan (Sone et al., 2008), Hungary (Skrabski, Kopp, Rózsa, Réthelyi, & Rahe, 2005) and the United States of America (Krause, 2009).

Although the above-mentioned studies support the assumption that positive psychological characteristics contribute to lower cardiovascular mortality, our knowledge is relatively limited and inconsistent about the physiological mediators of these associations (Aspinwall & Tedeschi, 2010). For instance, while in a study of 50 women no connection has been found between positive mood and heart rate variability (Myrtek, Aschenbrenner, & Brügner, 2005), other studies revealed positive associations between positive affect and enhanced parasympathetic cardiac control (Bhattacharyya, Whitehead, Rakhit, & Steptoe, 2008). Results concerning blood pressure are also mixed: while some findings support an inverse association between blood pressure and optimism or life purpose (Mezick et al., 2010; Räikkönen, Matthews, Flory, Owens, & Gump, 1999), other studies failed to verify the mediator role of blood pressure between positive psychological attributes and coronary heart disease (Boehm, Peterson, Kivimaki, & Kubzansky, 2011a; Ryff et al., 2006). Further studies pointed out that positive psychological constructs might also be associated with atherosclerosis and calcification (Matthews, Owens, Edmundowicz, Lee, & Kuller, 2006; Matthews, Räikkönen, Sutton-Tyrrell, & Kuller, 2004). However, these results are also inconsistent and most of the findings on these associations were related to only a small number of positive psychological attributes and were based on the same database of a single cohort of women (Boehm & Kubzansky, 2012).

The aim of the present study was to provide further data on the nature of the relationships between positive psychological variables and cardiovascular functioning, and to eliminate some of the shortcomings of previous research. As part of these efforts, a wider range of positive psychological variables was investigated in the present study including both eudaimonic, hedonic, and mixed nature indicators (Boehm & Kubzansky, 2012) providing the opportunity to compare the strength of associations of these (groups of) attributes with cardiovascular functioning. Furthermore, several measures of cardiorespiratory functioning were used simultaneously in a clinical and a healthy sample consisting of both males and females to avoid the bias of many previous investigations that resulted from the examination of only one clinical status and/or sex. Among the cardiorespiratory indicators, we also employed measures of arterial stiffness that, according to the best of our knowledge, have never been investigated regarding their relationship with positive psychological characteristics. Lastly, as a possible explanation for the previous inconsistent findings on the associations among positive attributes and cardiovascular functioning, nonlinear relationships were also taken into consideration.

We hypothesized that flourishing—as expressed by higher scores on the scales measuring satisfaction with life, psychological well-being, optimism, meaning in life, and sense of coherence—would be associated with more optimal cardiorespiratory functioning.

Method

Participants

The possible relationships of the cardiorespiratory and psychological variables were tested in a sample of patients who had been hospitalized with cardiovascular disease (CVD) and in a separate sample of healthy adults. The first sample consisted of 138 patients from the State Hospital of Cardiology (Balatonfüred, Hungary), while the second one consisted of healthy adult subjects (N=321) free of cardiorespiratory illness, who underwent the same tests as the cardiovascular patients at the Department of Radiology and Oncotherapy, Semmelweis University (Budapest, Hungary). These participants were recruited as part of a cardiovascular study investigating arterial stiffness (vascular aging) and its relationship to various risk factors for atherosclerosis. The refusal rate was low in both samples (1.5% in the clinical setting and 8% among healthy adults). Table 1 presents both cardiovascular and psychosocial characteristics of the samples showing that the two samples were statistically different across almost all of our indicators (with the exception of peripheral diastolic blood pressure and sense of coherence), which supports the stratification of the sample by clinical status.

Table 1. Demographical, psychological, and cardiorespiratory characteristics of the two samples (chi-square and Mann-Whitney tests).

	Clinical sample N=138	Healthy sample N=321	Difference	
	M (SD) / N (%)			
Sex (females)	67 (48.6%)	228 (71.3%)	χ^2=21.7	p<.001
Age (years)	65.3 (10.3)	42.6 (16.8)	*U*=5843.5	*p*<.001
Education (1-6)	2.5 (1.1)	3.8 (1.3)	*U*=10129.0	*p*<.001
Brachial augmentation index (%)	-0.3 (27.2)	-29.9 (32.2)	*U*=10445.5	*p*<.001
Aortic augmentation index (%)	32.5 (11.5)	22.3 (16.1)	*U*=12775.0	*p*<.001
Aortic pulse wave velocity (m/s)	11.5 (2.7)	8.7 (3.4)	*U*=9196.5	*p*<.001
Aortic systolic blood pressure (mmHg)	135.5 (21.7)	120.9 (20.4)	*U*=12.868.5	*p*<.001
Systolic area index (%)	51.9 (9.4)	48.4 (6.1)	*U*=14877.5	*p*<.001
Diastolic area index (%)	48.1 (9.4)	51.6 (6.1)	*U*=14872.5	*p*<.001
Peripheral systolic blood pressure (mmHg)	136.2 (18.6)	127.8 (16.9)	*U*=15793.0	*p*<.001
Peripheral diastolic blood pressure (mmHg)	76.3 (9.0)	75.1 (11.4)	*U*=19554.5	*p*=.075
Mean arterial pressure (mmHg)	96.3 (11.1)	92.7 (12.5)	*U*=17380.0	*p*<.001
Forced vital capacity (l)	2.4 (0.9)	3.0 (0.9)	*U*=12711.0	*p*<.001
Forced expiratory volume in one second (l)	1.5 (0.7)	3.7 (1.1)	*U*=1571.0	*p*<.001
Life satisfaction (5-25)	15.8 (3.9)	17.2 (4.1)	*U*=15910.5	*p*=.003
Well-being (5-25)	15.7 (4.5)	18.1 (4.0)	*U*=13689.0	*p*<.001
Optimism (6-30)	20.9 (3.4)	21.9 (4.1)	*U*=16456.0	*p*=.011
Meaning in life (8-40)	29.7 (5.4)	31.2 (4.8)	*U*=16343.5	*p*=.017
Sense of coherence (13-91)	66.4 (11.4)	66.4 (10.6)	*U*=17655.5	*p*=.939

Procedure

Data collection was conducted in 2009 and 2010. The institutional review board for human studies (Semmelweis University, Budapest, Hungary) approved the protocols and written consent was obtained from the subjects or their surrogates. Peripheral and central blood pressures and the non-invasive measurement of arterial stiffness were conducted first, after which a pulmonary function test was carried out. Finally, the participants were asked to complete the psychological test battery.

Measures

Cardiorespiratory variables

Endothelial dysfunction, which appears to occur in early atherosclerosis, affects the vascular structure, stiffness and thus the rate at which the pulse wave is propagated. The augmentation indexes provide extensive information on the arterial vascular system and it has been shown that this is closely correlated with cardiovascular risk (London et al., 2001). To evaluate arterial stiffness, the brachial augmentation index, the aortic augmentation index, and aortic pulse wave velocity were assessed non-invasively using the validated oscillometric method (Baulmann et al., 2008).[1] The TensioMed Arteriograph (1.10.1.1. software) was applied to individuals in supine positions by the second and third author of this study (trained by the manufacturer) so decreasing inter- and intra-observer variability. If the automatic quality control was appropriate at first (a standard deviation of $PWV_{ao}<1$) only one measurement was performed. In case of $SD_{PWVao}\geq 1$, the subject underwent at least three measurements.

In addition, peripheral systolic and diastolic blood pressures, mean arterial pressure, aortic systolic blood pressure, systolic area index, and diastolic area index were also measured. Central (aortic) systolic blood pressure was measured at the aortic trunk. Central blood pressure is a more direct measure than peripheral blood pressure of the hemodynamic stress imposed on the myocardium, and the coronary and cerebral circulation. In addition, it has a closer relationship to organ damage (Roman et al., 2010; Wang et al., 2009) and it may also be a more robust predictor of future cardiovascular complications (Roman et al., 2007). The heart cycle curve is divided into two parts by the ejection duration end-point constituting the systolic area index and the diastolic area index. These are the systolic and diastolic parts of the area under the entire pulse curve that characterize the ratios of coronary perfusion indices or 'cardiac fitness' (Brodskaia, Gel'tser, Nevzorova, & Motkina, 2007).[2] Mean arterial pressure, characterized by average blood pressure or perfusion pressure and determined by the cardiac output, the systemic vascular resistance and the central venous pressure, is also a reliable predictor of cardiovascular risk (Franklin, 2004).

Since it has already been shown that impaired lung function is also related to the development of cardiovascular mortality (Schroeder et al., 2003), respiratory parameters

[1] In the case of these three parameters, lower values indicate better cardiac functioning.

[2] Concerning systolic area index, lower values mean better cardiovascular health, in contrast to diastolic area index, where higher values indicate better physiological functioning.

were also included in our analyses. Observed forced vital capacity measures the amount of air that can be exhaled with force after an inhalation that is carried out as deeply as possible, while observed forced expiratory volume in one second measures the amount of air that can be exhaled with force in one breath.[3] These indicators, which are widely used to assess the extent of deterioration in lung function, were measured in the present study using dynamic spirometry (Lusuardi et al., 2006). The measurements were performed in accordance with guidelines recommended by the American Thoracic Society (Buist, 1987).

Psychosocial variables

Besides sex and age, educational level (six answer categories from primary school to doctoral level) was assessed in terms of sociodemographic characteristics. To assess hedonic well-being, scales measuring life satisfaction and general well-being were employed.

General life satisfaction was measured by the Hungarian version (Martos, Sallay, Désfalvi, Szabó, & Ittzés, 2014) of the five-item Satisfaction with Life Scale (Diener, Emmons, Larsen, & Griffin, 1985) ($\alpha_{\text{clinical sample}}$=.80; $\alpha_{\text{healthy sample}}$=.85). General psychological well-being of the respondents was assessed using the Hungarian version (Susánszky, Konkolÿ Thege, Stauder, & Kopp, 2006) of the WHO Well-being Index (Bech, Gudex, & Johansen, 1996). This five-item measure instrument also had good internal consistency in both of our samples ($\alpha_{\text{clinical sample}}$=.85; $\alpha_{\text{healthy sample}}$=.84). Dispositional optimism, a positive psychological characteristic including elements of both hedonic and eudaimonic well-being, was assessed by the Hungarian version (Bérdi & Köteles, 2010) of the revised Life Orientation Test (Scheier, Carver, & Bridges, 1994). This instrument proved to be reliable in our healthy sample (α=.73); however, its internal reliability coefficient was poor in the clinical sample (α=.50).

To investigate eudaimonic well-being, measure instruments of perceived life meaning and sense of coherence were employed. To assess meaning in life, the Hungarian version (Konkolÿ Thege, Martos, Skrabski, & Kopp, 2008) of the Life Meaning Subscale from the Brief Stress and Coping Inventory (Rahe & Tolles, 2002) was administered. The eight-item scale showed adequate internal consistency coefficients in our study ($\alpha_{\text{clinical sample}}$=.75; $\alpha_{\text{healthy sample}}$=.76). Sense of coherence was measured by the Hungarian version (Jeges & Varga, 2006) of the Sense of Coherence Scale (Antonovsky, 1993). This 13-item version of the instrument also proved to have adequate internal consistency in both of our samples ($\alpha_{\text{clinical sample}}$=.75; $\alpha_{\text{healthy sample}}$=.79).

In all cases, higher scores on the scales measuring psychological attributes indicated better psychological functioning. The intercorrelations among the positive psychology indicators were moderately strong (M=.40±.10). The highest Spearman correlation coefficient was observed between optimism and life satisfaction (*r*=.54; *p*<.001), while the weakest between sense of coherence and general well-being (*r*=.27; *p*<.001). These data show that although our psychological variables are not independent, their shared variances are less than 30% in all cases; therefore, it is reasonable to treat them as distinct constructs throughout the analyses.

[3] In both cases, higher values indicate better respiratory functions.

Statistical analyses

Potential differences in the demographical, psychological, and cardiorespiratory characteristics of the two samples were investigated using the chi-square test and the Mann-Whitney test because of the non-normal distribution of the variables. To examine the relationships between the positive psychological factors and the cardiorespiratory parameters, a separate analysis was conducted for each pair of them. Psychological indicators were used as independent variables, while the biological parameters as dependent variables. In all cases, the general linear model procedure was used and partial eta-squared coefficients were calculated to express effect size. The data were controlled for sex, age, and educational level in both samples.

Considering the relatively infrequent occurrence of these examinations in the literature and the explorative nature of this study concerning many cardiorespiratory indicators (e.g., markers of arterial stiffness), analyses were run to discover potential non-linear relationships as well. Thus, quadratic and cubic terms of the positive psychological factors, simultaneous to linear terms, were added to the models in a second and a third step to assess possible curvilinear relationships between the cardiorespiratory and psychological variables.

Considering the large number of associations analyzed, the necessity of applying standard Bonferroni correction [α / *k*; where α is the traditional criterion of significance (*p*≤.05) and k is the number of statistical tests conducted] was likely to arise. Using this method, the adequate level of significance in the present study should be set at *p*<.001 (.05/55). Since there is no clear consensus for when the Bonferroni procedure should be used and when it should not (Nakagawa, 2004), both corrected and non-corrected results will be considered for both subsamples. All statistical analyses were conducted using SPSS 20.0 software.

Results

Testing linear relationships

In the sample of participants with cardiovascular diseases (Table 2), satisfaction with life was significantly and negatively associated with peripheral systolic and mean arterial blood pressure indicating that persons being more satisfied with their lives have better cardiac functions. The other investigated cardiovascular and respiratory variables were unrelated with life satisfaction. Further, psychological well-being, dispositional optimism, and perceived meaning in life were unrelated to all of the investigated cardiorespiratory indicators in this sample. However, sense of coherence scores proved to be significant predictors of forced expiratory volume in one second. In this case again, a higher sense of coherence was related to better respiratory functioning.

Table 2. Multivariate associations between the positive psychological and the cardiorespiratory variables in the CVD sample (N=138) examined by the general linear model procedure.

	AIX_{bra}	AIX_{ao}	PWV_{ao}	SBP_{ao}	SAI	DAI	BP_{sys}	BP_{dia}	MAP	FVC	FEV_1
	F<.001	*F*<.001	*F*=.055	*F*=3.671	*F*=.382	*F*=.383	***F*=4.646**	*F*=3.399	***F*=4.983**	*F*=.129	*F*=.122
Life Satisfaction	*p*=.987	*p*=.991	*p*=.815	*p*=.058	*p*=.538	*p*=.537	***p*=.033**	*p*=.068	***p*=.027**	*p*=.720	*p*=.728
	η^2<.001	η^2<.001	η^2<.001	η^2=.030	η^2=.003	η^2=.003	**η^2=.038**	η^2=.028	**η^2=.041**	η^2=.001	η^2=.001
	R^2=.015	R^2=.015	R^2=.023	R^2=.119	R^2=.080	R^2=.080	**R^2=.131**	R^2=.048	**R^2=.089**	R^2=.455	R^2=.300
	F=1.208	*F*=1.192	*F*=.505	*F*=.089	*F*=.094	*F*=.098	*F*=.222	*F*=.106	*F*=.013	*F*=2.500	*F*=1.507
Well-being	*p*=.274	*p*=.277	*p*=.479	*p*=.766	*p*=.760	*p*=.755	*p*=.638	*p*=.746	*p*=.911	*p*=.116	*p*=.222
	η^2=.010	η^2=.010	η^2=.004	η^2=.001	η^2=.001	η^2=.001	η^2=.002	η^2=.001	η^2<.001	η^2=.021	η^2=.012
	R^2=.012	R^2=.012	R^2=.023	R^2=.078	R^2=.108	R^2=.108	R^2=.092	R^2=.019	R^2=.045	R^2=.492	R^2=.311
	F=.011	*F*=.009	*F*=.038	*F*=.012	*F*=.175	*F*=.173	*F*=.008	*F*=.551	*F*=.224	*F*=.307	*F*=3.240
Optimism	*p*=.916	*p*=.925	*p*=.845	*p*=.914	*p*=.676	*p*=.678	*p*=.929	*p*=.459	*p*=.637	*p*=.580	*p*=.074
	η^2<.001	η^2<.001	η^2<.001	η^2<.001	η^2=.002	η^2=.002	η^2<.001	η^2=.005	η^2=.002	η^2=.003	η^2=.027
	R^2=.007	R^2=.007	R^2=.029	R^2=.185	R^2=.075	R^2=.074	R^2=.093	R^2=.020	R^2=.050	R^2=.459	R^2=.298
	F=.066	*F*=.071	*F*=.011	*F*=.353	*F*=2.838	*F*=2.830	*F*=.260	*F*=.460	*F*=.472	*F*=.330	*F*=1.195
Meaning	*p*=.797	*p*=.791	*p*=.916	*p*=.554	*p*=.095	*p*=.095	*p*=.611	*p*=.499	*p*=.493	*p*=.567	*p*=.277
in life	η^2=.001	η^2=.001	η^2<.001	η^2=.003	η^2=.025	η^2=.025	η^2=.002	η^2=.004	η^2=.004	η^2=.003	η^2=.010
	R^2=.007	R^2=.007	R^2=.028	R^2=.070	R^2=.130	R^2=.129	R^2=.079	R^2=.018	R^2=.036	R^2=.473	R^2=.307
	F=2.967	*F*=2.991	*F*=2.240	*F*=.028	*F*=2.750	*F*=2.772	*F*=.123	*F*=.618	*F*=.068	*F*=.723	***F*=5.364**
Sense	*p*=.088	*p*=.087	*p*=.137	*p*=.868	*p*=.100	*p*=.099	*p*=.727	*p*=.434	*p*=.795	*p*=.397	***p*=.022**
of coherence	η^2=.027	η^2=.027	η^2=.021	η^2<.001	η^2=.026	η^2=.026	η^2=.001	η^2=.006	η^2=.001	η^2=.007	**η^2=.048**
	R^2=.020	R^2=.021	R^2=.015	R^2=.066	R^2=.142	R^2=.142	R^2=.075	R^2=.032	R^2=.041	R^2=.459	**R^2=.347**

Note. All associations are controlled for sex, age, and educational level. R^2 - adjusted R squared.
AIX_{bra} = brachial augmentation index; AIX_{ao} = aortic augmentation index; PWV_{ao} = pulse wave velocity on aorta; SBP_{ao} = aortic systolic blood pressure; SAI = systolic area index; DAI = diastolic area index; BP_{sys} = peripheral systolic blood pressure; BP_{dia} = peripheral diastolic blood pressure; MAP = mean arterial pressure; FVC = forced vital capacity; FEV_1 = forced expiratory volume in one second

In the sample of healthy adults (Table 3), in contrast to the clinical sample, satisfaction with life was not associated with any of the measured biological parameters. Similar to the clinical sample however, psychological well-being was unrelated to all of the investigated cardiorespiratory indicators. In this sample, dispositional optimism was significantly associated with the brachial augmentation index, the aortic augmentation index, and aortic systolic blood pressure. In all cases, higher optimism scores indicated lower vascular resistance and central blood pressure thus better cardiovascular functioning. The other cardiorespiratory variables were unrelated with dispositional optimism. Finally, meaning in life and sense of coherence scores were also independent from all biological parameters.

Table 3. Multivariate associations between the positive psychological and the cardiorespiratorical variables in the healthy sample (N=321) – examined by the general linear model procedure

	AIX_{bra}	AIX_{ao}	PWV_{ao}	SBP_{ao}	SAI	DAI	BP_{sys}	BP_{dia}	MAP	FVC	FEV_1
	F=.040	*F*=.010	*F*=.018	*F*=.356	*F*=1.731	*F*=1.720	*F*=.208	*F*=.128	*F*=.242	*F*=.015	*F*=1.644
Life	*p*=.842	*p*=.921	*p*=.893	*p*=.551	*p*=.189	*p*=.191	*p*=.649	*p*=.721	*p*=.623	*p*=.902	*p*=.201
Satisfaction	η^2<.001	η^2<.001	η^2<.001	η^2=.001	η^2=.006	η^2=.006	η^2=.001	η^2<.001	η^2=.001	η^2<.001	η^2=.006
	R^2=.530	R^2=.520	R^2=.428	R^2=.246	R^2=.040	R^2=.040	R^2=.079	R^2=.161	R^2=.134	R^2=.616	R^2=.618
	F=.929	*F*=.554	*F*=.048	*F*=.002	*F*=.012	*F*=.011	*F*=.015	*F*=.398	*F*=.052	*F*=1.788	*F*=.720
Well-being	*p*=.336	*p*=.457	*p*=.827	*p*=.968	*p*=.913	*p*=.915	*p*=.902	*p*=.529	*p*=.820	*p*=.182	*p*=.397
	η^2=.003	η^2=.002	η^2<.001	η^2<.001	η^2<.001	η^2<.001	η^2<.001	η^2=.001	η^2<.001	η^2=.006	η^2=.003
	R^2=.531	R^2=.521	R^2=.428	R^2=.246	R^2=.034	R^2=.034	R^2=.079	R^2=.162	R^2=.134	R^2=.619	R^2=.616
Optimism	***F*=4.313.**	***F*=4.414**	*F*=1.202	***F*=4.134**	*F*=.037	*F*=.039	*F*=1.678	*F*=1.160	*F*=1.616	*F*=.360	*F*=3.390
	***p*=.039**	***p*=.037**	*p*=.274	***p*=.043**	*p*=.847	*p*=.843	*p*=.196	*p*=.282	*p*=.205	*p*=.549	*p*=.067

	AIX_{bra}	AIX_{ao}	PWV_{ao}	SBP_{ao}	SAI	DAI	BP_{sys}	BP_{dia}	MAP	FVC	FEV_1
	η^2=.015 **R^2=.536**	**η^2=.015** **R^2=.527**	η^2=.004 R^2=.430	**η^2=.014** **R^2=.256**	η^2<.001 R^2=.034	η^2<.001 R^2=.034	η^2=.006 R^2=.084	η^2=.004 R^2=.164	η^2=.006 R^2=.138	η^2=.001 R^2=.617	η^2=.012 R^2=.620
Meaning in life	F=.002 p=.967 η^2<.001 R^2=.530	F=.001 p=.973 η^2<.001 R^2=.520	F=.053 p=.818 η^2<.001 R^2=.428	F=.010 p=.922 η^2<.001 R^2=.246	F=.152 p=.697 η^2=.001 R^2=.034	F=.149 p=.700 η^2=.001 R^2=.034	F=.024 p=.878 η^2<.001 R^2=.079	F=.030 p=.863 η^2<.001 R^2=.161	F=.013 p=.909 η^2<.001 R^2=.133	F=.231 p=.631 η^2=.001 R^2=.617	F=.150 p=.699 η^2=.001 R^2=.616
Sense of coherence	F=.945 p=.332 η^2=.003 R^2=.531	F=.915 p=.340 η^2=.003 R^2=.521	F=1.416 p=.235 η^2=.005 R^2=.431	F=.543 p=.462 η^2=.002 R^2=.247	F=.262 p=.609 η^2=.001 R^2=.035	F=.268 p=.605 η^2=.001 R^2=.035	F=.624 p=.430 η^2=.002 R^2=.081	F=.346 p=.557 η^2=.001 R^2=.162	F=.457 p=.500 η^2=.002 R^2=.135	F=.889 p=.347 η^2=.003 R^2=.617	F=.503 p=.479 η^2=.002 R^2=.616

Note. All associations are controlled for sex, age, and educational level. R^2 - adjusted R squared.
AIX_{bra} = brachial augmentation index; AIX_{ao} = aortic augmentation index; PWV_{ao} = pulse wave velocity on aorta; SBP_{ao} = aortic systolic blood pressure; SAI = systolic area index; DAI = diastolic area index; BP_{sys} = peripheral systolic blood pressure; BP_{dia} = peripheral diastolic blood pressure; MAP = mean arterial pressure; FVC = forced vital capacity; FEV_1 = forced expiratory volume in one second

Non-linear relationships and Bonferroni correction

Entering the quadratic and cubic terms of all the positive psychological attributes to the models, further relationships emerged (see Appendix for scatter plots with the fitting curves). In the sample of CVD patients, the quadratic term of perceived meaning in life was a significant predictor of forced vital capacity (U-shaped curve; F=7.231; p=.008; η^2=.061; R^2=.500).

In the healthy sample, again different patterns were observed. The cubic term of satisfaction with life proved to be a significant predictor of pulse wave velocity on aorta (sigmoid curve; F=4.318; p=.039; η^2=.015; R^2=.433). Further, while the quadratic term of optimism was associated with forced vital capacity (inverted U-shaped curve; F=4.416; p=.037; η^2=.016; R^2=.621), its cubic term predicted both systolic (sigmoid curve; F=4.081; p=.044; η^2=.014; R^2=.045) and diastolic area index (inverse sigmoid curve; F=4.113; p=.043; η^2=0.014; R^2=.046). Finally, adding the quadratic term of sense of coherence to the models, explained variance increased in the case of pulse wave velocity on aorta (U-shaped curve; F=6.749; p=.010; η^2=.023; R^2=.442), while the cubic term of this positive psychological attribute proved to be a significant predictor of the aortic augmentation index (inverse sigmoid curve; F=3.795; p=.052; η^2=.013; R^2=.529) and peripheral diastolic blood pressure (inverse sigmoid curve; F=4.489; p=.035; η^2=.015; R^2=.169).

As the displayed p-values show, using the Bonferroni correction, none of the analyzed associations—independent of being linear or non-linear—proved to be significant for either of the samples.

Discussion

Over the past two decades, many studies have shown that positive psychological phenomena play an important role in cardiac health. However, our knowledge is limited and inconsistent about the specific biological means through which these components of human flourishing may be associated with the etiology and progression of heart diseases. For instance, most of the work on the physiological correlates of positive attributes has focused on optimism or transitory positive states, investigated either clinical or healthy populations, and their samples often consisted of only one sex (Boehm & Kubzansky, 2012; DuBois et al., 2012).

The purpose of the present study was to investigate whether various positive psychological constructs were related to some cardiovascular and respiratory indicators that have been linked to the formation of cardiovascular diseases. To the best of our knowledge, this is the first study on this topic that: (1) analyzes a larger pool of positive psychological variables simultaneously including both eudaimonic and hedonic well-being indicators; (2) utilizes several sophisticated cardiovascular and respiratory parameters, including arterial stiffness indicators; (3) includes both males and females with and without cardiovascular disease when investigating the associations of positive psychological characteristics with cardiovascular parameters.

In line with our assumptions, higher satisfaction with life was associated with lower mean arterial pressure and peripheral systolic blood pressure, while stronger sense of coherence were related to better respiratory functioning in the sample consisting of persons suffering from some kind of heart disease. Among participants of the healthy sample, optimism was associated with lower aortic systolic blood pressure and the augmentation indexes. Although the pattern of the significant associations were different across the samples, the direction of all observed linear relationships was in accordance with our basic assumptions, i.e., that positive psychological states related to better cardiac functioning.

An important feature of our study was the investigation of an often-neglected aspect of the literature, i.e., the examination of potential non-linear relationships among positive psychological attributes and physiological parameters. Similar to the linear associations, most of the tested connections were not significant but the direction of those proved to be significant were largely in line with our hypotheses. However, these data should direct our attention to the importance of avoiding over-simplification when examining the beneficial role of different kinds of well-being in physical health. The inverted U-shaped relationship between optimism and respiratory functions observed in the healthy sample of the present study, for instance, might refer to the possibility of Aristotle's idea that the mean is the most appropriate approach towards at least some positive psychological attributes (Grant & Schwartz, 2011; Milam, Richardson, Marks, Kemper, & McCutchan, 2004). Future research in this area, therefore, should routinely consider non-linear associations including threshold and ceiling effects as well, which might contribute to the clarification of the inconsistencies previously found.

When evaluating the overall picture of the results, particular attention should be paid to the fact that, even if several tested associations were significant (according to the traditional p-value of .05), most of the analyzed relationships among the cardiorespiratory and the positive psychology indicators were not significant. Furthermore, even in the case of significant associations, the effect sizes usually showed that the relations were relatively weak. The cross-sectional nature of the study also limits the possibility of establishing causal inferences even in the case of significant relationships. Further, the associations among the biological and psychological parameters did not seem to follow a consistent pattern; instead, several psychological attributes were completely independent from the biological indicators, while others were associated with different cardiorespiratory variables. In addition, when applying the Bonferroni correction, considering the large number of tested associations, none of the analyzed relationships proved to be significant for either of the two samples, which may also indicate that the emerged connections might rather be considered as the result of chance.

Therefore, based on the results of the present study, no cardiorespiratory variables could be offered with strong certainty for subsequent formal mediation analysis that could aim to clarify the paths between positive psychological phenomena and decreased cardiovascular morbidity and mortality. Other researchers came to similar conclusions when not finding cardiovascular parameters to mediate between positive psychological well-being and coronary heart disease (Boehm et al., 2011a). The results of the present study suggest that future research should include additional potential mediator factors between flourishing and cardiovascular morbidity, such as ejection fraction, coronary calcification, inflammatory factors, aldosterone, antioxidants and cortisol levels (cf. Boehm, Williams, Rimm, Ryff, & Kubzansky, 2013; Kubzansky & Adler, 2010; Nasermoaddeli, Sekine, & Kagamimori, 2006; Steptoe, Demakakos, de Oliveira, & Wardle, 2012).

Nevertheless, it is worth mentioning that, although the present study analyzed data from two different samples, both groups were derived from the same country. Therefore, cultural characteristics could also affect the results. For instance, standard deviations of some of the psychological indicators utilized in this study were smaller when compared to several previous studies from other cultures (Bech, Olsen, Kjoller, & Rasmussen, 2003; Eriksson & Lindström, 2005; Glaesmer, Hoyer, Klotsche, & Herzberg, 2008; Löwe et al., 2004). Further, not only standard deviations but also the means of the positive attributes may be lower than in the countries where the associations between positive psychology characteristics and cardiovascular health had previously been reported. For example, a recent study suggests that native Hungarians are more pessimistic than persons from other nations, regardless of which country they presently live in (Tóth & Kovács, 2011). These considerations raise the possibility that the variability or perceived level of positive psychological characteristics in the culture investigated here does not or hardly reaches a level at which their protective effects on health could be demonstrated (cf. necessity of testing threshold effects as described above).

The potential strengths and limitations of our study should also be considered. All the arterial stiffness and pulmonary function tests were performed by the same trained researchers, and the same device and protocol increasing the reliability and consistency of cardiorespiratory measurement. However, the clinical sample consisted of patients under rehabilitation therapy; therefore, pharmacotherapy might have influenced many of the cardiovascular and perhaps positive psychology indicators as well. Recent cardiac surgery could also influence the respiratory data among persons with cardiovascular diseases. These factors may explain some of the null results concerning this subsample. The Cronbach-alpha coefficient of the optimism scale (LOT-R) was also under the limit of acceptability in the clinical sample, thus limiting the reliability of the results concerning this variable in the CVD sample.

Further, although several sophisticated cardiological parameters were assessed in this study, even more reliable data could have been collected with repeated measurement concerning some variable parameters, for example peripheral blood pressure. A further limitation is the absence of negative psychological indicators (e.g., depression, hostility) that would have given the opportunity to clearly decide whether better physiological functions should be attributed to the presence of positive characteristics or to the absence of negative ones. However, several studies suggest that cardiovascular benefits associated with positive psychological variables may be more than merely the absence of negative states (DuBois et al., 2012; Katri Räikkönen & Matthews, 2008; Ryff et al., 2006). Finally, many potentially relevant covariates (e.g., health behaviors, body mass index) were not included in the present analyses; however, considering the mostly negative findings, the inclusion of these variables most likely would not have affected substantially the inferences drawn from the data.

We can conclude that further research is needed to determine whether the mostly negative findings of the present study derive from cultural specificity or whether they reliably indicate that the mediators between psychological flourishing and cardiovascular health should be sought among cardiorespiratory variables other than the ones included in the present investigation.

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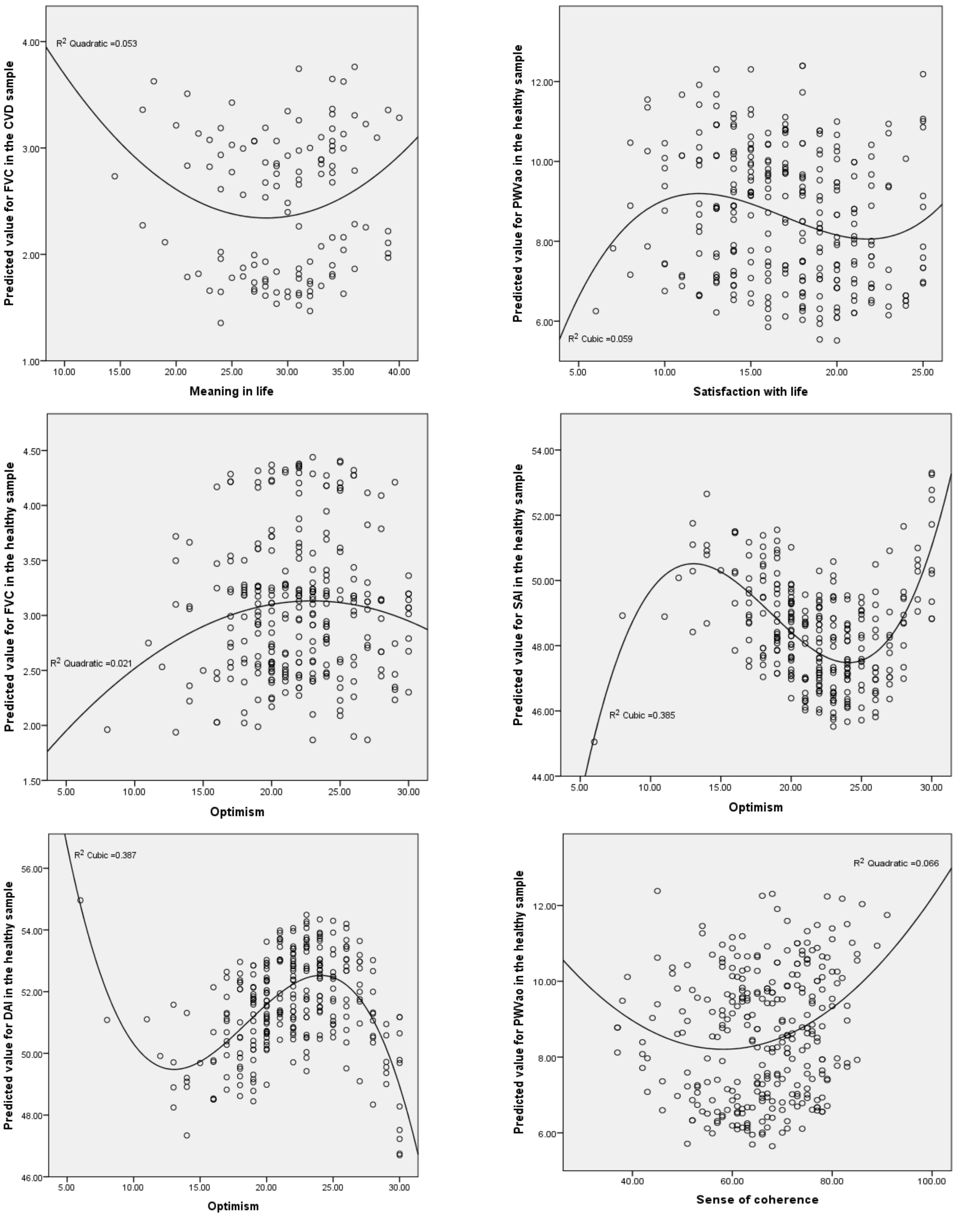
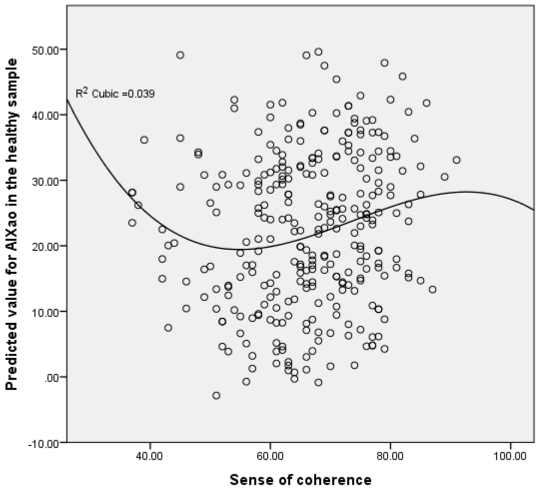
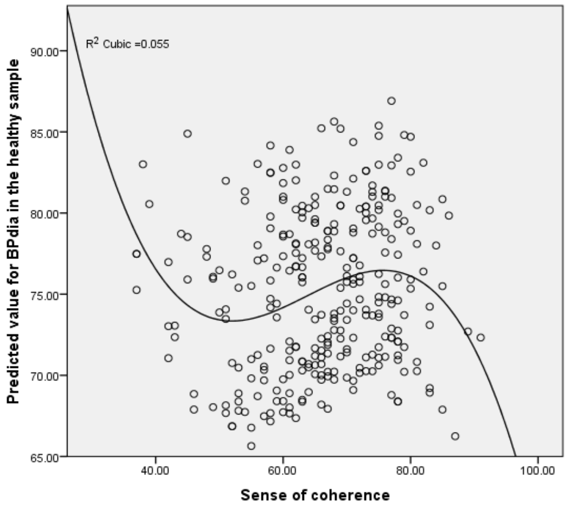
Appendix: Significant non-linear relationships between the positive psychology attributes and the cardiovascular indicators (for explanations of abbreviations, see Table 2 or 3




R^2 Cubic =0.039
Predicted value for AIXao in the healthy sample
Sense of coherence
50.00
40.00
30.00
20.00
10.00
.00
-10.00
40.00
60.00
80.00
100.00


R^2 Cubic =0.055
Predicted value for BPdia in the healthy sample
Sense of coherence
90.00
85.00
80.00
75.00
70.00
65.00
40.00
60.00
80.00
100.00