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Short communication

Heart rate variability as a marker of healthy ageing

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ABSTRACT

Background: With population ageing a significant concern, modifiable factors contributing to healthy ageing must be identified. Autonomic responding reflected by heart rate variability (HRV) has well-established links to general health and wellbeing in younger populations; but has yet to be explored in older individuals.
Methods: Forty-five healthy participants (49–82 years old) completed questionnaires about sleep and physical and psychological health. Autonomic activity was measured during rest and whilst completing a computerised battery of cognitive tasks. Participants then wore an ambulatory heart rate monitor overnight, and recorded their sleep and physical activity for one week. HRV parameters reflecting cardiac vagal tone were derived from electrocardiograph recordings.
Results: Age and resting HRV were not related; however a positive association was identified between higher HRV in the 2 h prior to sleep and older age. Higher resting HRV, older age, and better sleep quality significantly predicted psychological wellbeing; and fewer somatic and physical health symptoms and older age predicted better average sleep quality ratings. Older age and poorer general health were significant predictors of cognitive performance deficits.
Conclusion: These findings suggest that an age-related decline in HRV is not inevitable. Longitudinal designs exploring within-individual changes in cardiac vagal tone are required to better understand the factors contributing to healthy ageing.

1. Introduction

Population ageing represents a significant public health challenge in many countries worldwide [1]. It is therefore imperative that medical research identifies modifiable factors that facilitate healthy ageing. The autonomic nervous system (ANS) is one of the key regulatory systems perturbed by ageing, which may potentiate changes in sleep/wake patterns, and contribute to cognitive difficulties and neuropsychiatric symptoms [2–5].

Autonomic function can be estimated non-invasively from electrocardiograph (ECG) recordings [6,7]. Strong links have been identified between heart rate variability (HRV) parameters and wellbeing; with low HRV (reflecting a reduction in parasympathetic activity and a shift towards greater sympathetic dominance) associated with impairments in sleep, executive cognitive function as well as emotional and physical wellbeing both in healthy adults, and patients suffering from a wide variety of medical and neuropsychiatric conditions [8,9].

HRV is generally thought to decline with age [10,11]; with lower cardiac vagal tone in older individuals being found to be associated with cognitive impairment and functional decline [12,13]. However, these studies have generally assessed older individuals with health conditions. Thus it is unclear if the observed changes in ANS functioning are due to age-related bodily changes (physical fitness and body habitus), lifestyle factors (chronic alcohol or tobacco use, and obesity), or an increasing number of pathophysiological changes that impede optimal functioning of the body [11,14].

This exploratory study aims to examine if reductions in HRV reflecting cardiac vagal tone are inevitably linked to ageing even in healthy individuals. A second objective is to examine whether previously established relationships in younger individuals between HRV and sleep quality, cognitive performance, and psychological wellbeing are maintained in this healthy older group.

2. Methods

Forty-five healthy participants (mean age = 61.6, SD = 7.5, 28 females) with no known hearing loss, self-reported medical conditions, or medication use that may interfere with autonomic assessment were recruited through community advertisements. Participants were stratified by age (based on median split) into "younger" (age ≤ 61 years)

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and "older" (age ≥ 62 years) groups. All participants attended a single, 75 min laboratory assessment. After completing self-report questionnaires concerning basic demographic information, sleep, and physical and psychological health, participants sat in a comfortable, semi-reclined position. Laboratory-based measures of heart rate (three-lead ECG) and respiration (strain gauge transducer) were continuously recorded whilst participants listened to a gentle nature soundscape for 10 min to establish their baseline autonomic activity; and during the completion of three computerised cognitive tasks (Psychomotor Vigilance Task, Digit Symbol Coding Task, Stroop task). Overall cognitive performance was derived by principal component analysis. Participants were fitted with an ambulatory heart rate and activity monitor (Equivital; Hidalgo, Cambridge UK) to wear while going about their normal daily routine, including sleep, until the following morning. HRV measures were derived from the R-R intervals of ECG recordings in 5 min epochs using LabChart 8, which utilises the Lomb-Scargle periodogram to determine the high frequency (HF) spectral component (0.15–0.40 Hz), a well validated marker of parasympathetic, vagal activity [6,15]. Ambulatory HRV data was not available for two participants due to technical errors ($n = 1$), or failure to adhere to the testing protocol ($n = 1$). Participants also completed a daily sleep and activity diary for one week. This investigation conformed to the ethical guidelines of the 1975 Declaration of Helsinki as reflected by approval by the institutional human research ethics committee (HREC Approval #HC15768) and written informed consent was obtained from all participants. All analyses were conducted in SPSS version 24 (IBM, Chicago, IL, USA).

Table 1
Sample demographic, clinical and lifestyle characteristics, and autonomic and HRV parameters during rest, stratified by age. Data are presented as mean (standard deviation) unless otherwise specified.

Participant characteristics	Younger ($n = 22$)	Older ($n = 23$)	*Combined* ($n = 45$)
Sex			
Male, *n* (%)	8 (36)	9 (39)	*17 (38)*
Female, *n* (%)	14 (64)	14 (61)	*28 (62)*
Age (years)	55.55 (4.01)	67.35 (5.17)	*61.58 (7.52)*
Medication use, *n* (%)	6 (27)	9 (39)	*15 (33)*
Antihypertensives	4	2	*6*
Low-dose aspirin	2	1	*3*
Selective serotonin reuptake inhibitors	–	1	*1*
Statins	3	5	*8*
Thyroxin	1	2	*3*
Body mass index (BMI; kg/m^2)	25.04 (4.92)	25.25 (3.80)	*25.15 (4.34)*
MoCA[a]	28.36 (1.56)	28.35 (1.23)	*28.36 (1.38)*
Caffeine consumption (cups/day)	2.59 (1.59)	2.35 (1.30)	*2.47 (1.44)*
Alcoholic drinks (std drinks/week)	4.36 (4.96)	4.57 (5.67)	*4.47 (5.28)*
Total exercise (hours/week)	7.86 (14.43)	7.89 (8.01)	*7.88 (11.46)*
SPHERE			
Somatic symptom subscale	0.91 (1.19)	0.91 (1.53)	*0.91 (1.36)*
Psychological symptom subscale	1.09 (1.82)	0.39 (0.72)	*0.73 (1.41)*
Total symptom score	3.95 (4.87)	3.78 (5.20)	*3.87 (4.98)*
Health-related quality of life (SF36)			
Mental component summary[a]	80.74 (13.34)	82.89 (9.23)	*81.84 (11.35)*
Physical component summary[a]	84.63 (8.99)	82.40 (9.37)	*83.49 (9.15)*
Sleep quality (PSQI)	3.91 (2.98)	3.91 (1.81)	*3.91 (2.42)*
Pain (McGill)	2.09 (2.86)	3.43 (4.42)	*2.78 (3.76)*
Perceived stress (PSQ)	56.05 (20.00)	50.04 (9.04)	*52.98 (15.52)*
Psychological distress (K10)	13.27 (4.99)	12.83 (3.06)	*13.04 (4.07)*
Epworth sleepiness scale (ESS)	4.68 (2.98)	6.17 (3.71)	*5.44 (3.42)*
Patient health questionnaire (PHQ9)	2.59 (3.33)	2.17 (2.21)	*2.38 (2.79)*
Resting autonomic and HRV parameters			
Heart rate (beats p/min)	63.98 (8.71)	63.21 (8.64)	*63.59 (8.58)*
Respiratory rate (breaths p/min)	13.82 (2.99)	13.34 (2.08)	*13.58 (2.56)*
RMSSD (ln(ms))	3.17 (0.56)	3.17 (0.77)	*3.17 (0.67)*
Total spectral power (ln(μs^2))	7.07 (0.92)	6.88 (1.11)	*6.97 (1.02)*
HF spectral power (ln(μs^2))	5.40 (1.31)	5.23 (1.41)	*5.31 (1.35)*
HF spectral power (nu)	46.64 (21.56)	47.30 (20.09)	*46.97 (20.59)*

MoCA: Montreal Cognitive Assessment; SPHERE: Somatic and Psychological Health Report; SF36: Medical Outcomes Study 36-item Short Form Health Survey; PSQI: Pittsburgh Sleep Quality Index; PSQ: Perceived Stress Questionnaire; K10: Kessler Psychological Distress Scale; HRV: heart rate variability; RMSSD: root mean square of successive R-R interval differences; HF: high frequency band (0.15–0.4 Hz).

[a] Indicates that a higher score reflects better functioning.

3. Results

Demographic, clinical, and lifestyle characteristics of the 45 participants are displayed in Table 1. Independent samples *t*-tests revealed no significant differences between older and younger groups on any self-reported questionnaire measure. Notably, the majority of the participants recruited in this sample endorsed very few physical or psychological symptoms. Similarly, no group differences were observed on any resting HRV parameter, so analyses were based on individual differences apparent in the sample as a whole. Similarly, the analyses reported below utilised HF (in normalised units; nu) HRV as a marker of cardiac vagal tone [15]; sensitivity analyses using the root mean square of successive differences in R-R intervals (RMSSD) were also conducted which generated compatible results.

There was no association between age and resting state HRV ($r(44) = 0.10$, $p = 0.53$); yet HRV in the 2 h preceding sleep was associated with age, with older participants showing greater HRV ($r(42) = 0.41$, $p = 0.006$). Most variables showed no significant correlation with age including sleep quality ($r(44) = -0.07$, $p = 0.64$) and somatic symptoms ($r(44) = -0.02$, $p = 0.88$), however the endorsement of psychological symptoms was inversely associated with age ($r(44) = -0.36$, $p = 0.014$). Multiple linear regression found that poorer sleep quality ($B = 0.31$, 95% CI: 0.18 to 0.44, $p < 0.001$), lower resting baseline HRV ($B = -0.02$, 95% CI: -0.04 to -0.01, $p = 0.011$) and younger age ($B = -0.06$, 95% CI: -0.10 to -0.01, $p = 0.012$) were all significant independent predictors of greater psychological symptoms.

Poorer sleep quality was linked with greater psychological ($r(44) = 0.53$, $p < 0.001$) and somatic symptoms ($r(44) = 0.49$, $p = 0.001$) and higher levels of perceived stress ($r(44) = 0.48$, $p = 0.001$). Moreover, multiple linear regression modelling identified that more refreshing sleep was associated with older age ($B = 0.06$, 95% CI: 0.01 to 0.12, $p = 0.014$) and fewer somatic and physical health symptoms ($B = -0.20$, 95% CI: -0.28 to -0.12, $p < 0.001$). The inclusion of autonomic and sleep duration parameters did not improve the model fit.

Finally, both older age ($B = 0.06$, 95%CI: 0.03 to 0.10, $p = 0.001$) and reduced general health ($B = -0.03$, 95% CI: -0.05 to 0.00, $p = 0.03$) significantly predicted poorer overall cognitive performance. Resting state HRV failed to make a significant unique contribution to the final model.

4. Discussion

There was no clear association between age and resting HRV in our healthy older participants. Moreover, a positive association was observed between age and HRV in the hours leading up to sleep. These results are in contrast to previous studies demonstrating an age-related decline in HRV [11,14] and may be explained by the targeted recruitment in many of these studies of participants with a physical and/or mental impairment [12,13]. As such, the age-associated decline in cardiac vagal tone may reflect a general decline in wellbeing rather than age specifically. In the current study, by only recruiting healthy individuals reporting no major physical or mental health concerns we may have generated a healthy survivor bias [16]. These results suggest that an age-related decline in HRV is not inevitable and cardiac vagal tone in respect to ageing may be better utilised as a way of predicting dysfunction (or lack thereof) and informing management strategies to promote healthy ageing.

Research on healthy community dwelling older adults suggests that cognitive functioning declines gradually with age, particularly beyond 70 years [4]. Other studies have shown that high levels of cognitive performance are associated with better mental and physical functioning [17]. Commensurate with these findings, increasing age and poorer general health were found to be significant predictors of poorer cognitive performance. At odds with the natural cognitive and physical decline that tends to occur with ageing, older adults enjoy high levels of affective wellbeing and emotional stability [4,18]. Concordant with existing findings, older age was associated with better psychological health. A possible explanation could be that increasing age is associated with an increased competence to regulate emotional states, due to experience and maturation in certain perspectives in life [19]. Regression modelling also identified that older age, greater HRV at rest and better sleep quality significantly predicted psychological wellbeing. These findings are consistent with previous studies linking higher resting HRV with more adaptive self-regulation and social engagement [8]. Finally, the relationship between sleep quality and psychological symptoms can be bi-directional, with emotional states influencing sleep patterns [20]. Indeed, we found that fewer somatic and psychological health symptoms and older age predicted better sleep quality over a week, and the longer-term index of sleep quality (PSQI) significantly predicted psychological symptoms.

The cross-sectional nature of this study, and others [8,12], make it difficult to determine the directionality of age, HRV and health associations. Large longitudinal cohort studies following healthy individuals over prolonged periods are essential to accurately assess these relationships, and explore if within-individual changes in autonomic activity precede or follow physical and mental health changes.

5. Conclusion

This unique exploration of the association between autonomic functioning, sleep quality, cognitive functioning, and psychological wellbeing adds a number of novel insights to the existing literature on ageing. We found no age-associated decline in HRV in an older sample endorsing very few physical or psychological symptoms. Cognitive performance was less accurate and slower with increasing age, but not associated with autonomic activity. Overall, increasing age was associated with better psychological health and sleep quality. In light of an ageing population, there remains a pressing need to better understand factors that contribute to improved wellbeing and functioning for older individuals. These results indicate that HRV reflecting cardiac vagal tone may be a useful index of wellbeing in older individuals, and moreover, may be a modifiable factor which can be targeted to facilitate healthy ageing.

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Conflicts of interest

The authors report no relationships that could be construed as a conflict of interest.

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