Sexuality is a major way of intimacy in human being and it is very important in gender relationship, contributing to over all health. However, since association between sexual activity and sudden death determined by forensic autopsies related to cardiac or cerebral causes has been reported, some people with heart disease often abstain from sexual activity that could affect the quality of life. It is therefore important to learn the physical demand of sexual activity and the risk it may trigger. For decades, the cardiologists have conducted observational studies and clinical trials on healthy volunteers or patients. The most common indices responding to cardiovascular risks of sexuality were variances of blood pressure (BP) and heart rate (HR), monitored by ambulatory blood pressure and dynamic electrocardiogram recording. BP and HR increase during the coitus just briefly and quickly recover to baseline level. Peak coital BP occurred at onset of plateau phase and quickly decreased, instead of emerged at orgasm as most people supposed. The metabolic equivalent of energy expenditure during the orgasm was relatively modest when compared with other physical exertion such as cycling. Epidemiological studies have suggested that sexual activity has favorable effect on health in the long term. This review summarizes and discusses the advances in the researches dealing with cardiovascular effects of sexual activity to better inform the cardiac patients.

Key words Cardiovascular system - risk - sexual activity - sudden death

Introduction

Effect of sexual activity on health has long been a debated topic with focus on cardiovascular system. Patients with heart disease often have fear of coital sudden death or triggering a cardiac event, which actually lower their quality of life. Physiological and clinical aspects of sexual function have been extensively studied in patients who have angina, have experienced a myocardial infarction$^1$-$^5$, have undergone coronary artery bypass graft surgery$^6$ or heart transplant$^7$ and those with chronic heart failure$^8$. A better understanding of cardiovascular effects of sexual activity may help clinicians to identify strategies for prevention and offer valuable suggestion. This article reviews literature on various epidemiological, observational, randomized trials and self-reported surveys during the last five decades.

Adverse effect of sexuality on cardiovascular system

Coital death: Coital death has often been attributed to various causes such as cardiac disease or intracerebral haemorrhage. Like any form of physical exercise or anger, sexual activity increases heart rate (HR) and blood pressure (BP), and it has been identified as a
trigger for myocardial infarction (MI)\textsuperscript{9}, or even sudden death, especially for those with heart disease\textsuperscript{10}. To fill up the gap of lack of data and insufficient information, four major studies were initiated to determine the risk of sudden death based on autopsy findings (Table I)\textsuperscript{11-14}.

In the death examination archived in Berlin\textsuperscript{11} from 1956 to 1976, 30 (1.7\%) of 1722 forensic autopsies were described as unexpected deaths occurring during sexual activity. Only 2 cases were women. Twenty three cases of fatal events were preceded by extra-marital intercourse. Of the 30 deaths, five took place before, 9 during and 16 after the coitus. These findings were consistent with data from another large-scale German study, which was a medico-legal post-mortem study performed in Frankfurt over a 33-yr period, about 31691 forensic autopsies revealed 68 (0.22\%) natural deaths occurring during sexual activity\textsuperscript{12}. Most of the deaths occurred in men (92.6\%). The majority of the deaths occurred during extra-marital intercourse (n=39). Only 19 of the fatal events occurred in the victim’s home (n=16) or the home of long time partner (n=3). The pathological findings of this autopsy study (1972-2004) revealed that sexual activity with an extra-marital partner could pose a risk of health for those with cardiac disease. Among the causes of death, coronary artery disease (CAD) without signs of myocardial infarction accounted for one third cases, followed by myocardial reinfarction and MI.

In Asia, the study results of Ueno\textsuperscript{13} in Japan and Sanghan Lee and colleagues in Korean\textsuperscript{14} were consistent with the western data that men were the major victims of sudden death in the context of extra-marital relations and their underlying cardiovascular disease led to death predominantly. It is presumed that the secret immoral sexuality in unfamiliar setting or alcohol or heavy food may significantly increase the BP and HR, resulting in sudden death or cardiovascular events\textsuperscript{14}; however the chances of it are very low. Indeed, the increase in risk attributed to coitus was found to be far less than that associated with anger and unaccustomed physical exercise, and during the 2 to 4 h after awakening associated with diurnal variation\textsuperscript{15}.

**Mechanism of cardiovascular risks related to sexual activity:** The most likely mechanism for the triggering effect of heavy physical exertion and sexual activity is increased sympathetic activity, particularly in non trained individuals. Increased HR, BP, platelet aggregability and increased coronary vasomotor tone may be involved as potential underlying mechanisms\textsuperscript{16}, by which a potential transient exposure may trigger MI related to the existence of vulnerable atherosclerotic plaques. Heavy physical exertion, including sexual activity, could induce a cascade of events resulting MI through their effect on the sympathetic nervous system. Other acute exposures may trigger cardiovascular disease through different mechanisms\textsuperscript{17,18}.

**Exercise tolerance of sexual activity:** In comparing sexual activity with other forms of activity, the most commonly used clinical measure is the metabolic equivalent of energy expenditure (MET). For comparison, walking at 2 mph on level ground would equate to 2 METs; walking at 3 mph, 3 METs. Preorgasm of sexual activity averages 2-3 METs; orgasm during sexual activity 3-4 METs. Compared to higher-intensity physical exertion, such as cycling at 10 mph (6-7 METs) or walking on the treadmill (13 METs), the exertion of sexual activity is relatively modest\textsuperscript{19}. Level of sexual function appears to have a significant link with the 6 min walk test\textsuperscript{20}. Hellerstein & Friedman first suggested that the equivalent oxygen cost of the average maximum HR during sexual activity was less than that of climbing two flights of stairs or walking briskly\textsuperscript{2}. Larson \textit{et al}\textsuperscript{21} compared the HR and BP responses to both sexual activity and stair-climbing and found no difference in HR response in coronary artery disease (CAD) patients.

<table>
<thead>
<tr>
<th>Study</th>
<th>Period</th>
<th>Autopsy scale</th>
<th>Coital death</th>
<th>Male victims</th>
<th>Extra-marital sexuality</th>
<th>Proportion of cardiac or cerebral death (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany\textsuperscript{11}</td>
<td>1956-1976</td>
<td>1722</td>
<td>30</td>
<td>28</td>
<td>23</td>
<td>15 (50)</td>
</tr>
<tr>
<td>Germany\textsuperscript{12}</td>
<td>1972-2004</td>
<td>31691</td>
<td>68</td>
<td>63</td>
<td>39</td>
<td>35 (51.5)</td>
</tr>
<tr>
<td>Japan\textsuperscript{13}</td>
<td>1959-1965</td>
<td>8275</td>
<td>67</td>
<td>65</td>
<td>47</td>
<td>32 (47.8)</td>
</tr>
<tr>
<td>Korean\textsuperscript{14}</td>
<td>2001-2005</td>
<td>1379</td>
<td>14</td>
<td>9</td>
<td>10</td>
<td>12 (85.7)</td>
</tr>
</tbody>
</table>

Superscript numerals represent Ref. no.
between these two activities. However, the average systolic blood pressure was significantly higher in stair climbing compared to that of sexual intercourse. While Bohlen et al. suggested that the challenge of two flights of stairs might not apply to all patients, Drory regarded that equating energy expenditure during coitus with ‘climbing two flights of stairs’ was a potentially misleading oversimplification.

Attitude towards sexual activity and its effect

Impaired sexual activity: Although coital death for cardiac patients is rare and its cardiovascular risk is low, it still exists, which prevents many people from sexual activity for fear that it may cause sudden death or reinfarction, dyspnoea, anxiety, angina pectoris, exhaustion, changes in sexual desire, depression, loss of libido, impotence, partner’s anxiety or concern, and feeling of guilt. Fear of a cardiac event during sexual intercourse can interfere with patients’ ability to perform and enjoy sexuality. For example, unstable angina and non-ST evaluation MI patients have a negative impact on frequency of, and satisfaction with, sexual activity, and lead to sexual dysfunction within a large number of female patients. Those with CAD have a more than two-fold risk of sexual dysfunctions compared with age-matched healthy persons. It is well known that sexual activity is reduced in patients with coronary disease. In men with chronic heart failure, sexual activity is depressed.

Many men with established cardiovascular disease have erectile dysfunction (ED), the inability to achieve and maintain an erection sufficient to permit satisfactory sexual intercourse. Endothelial dysfunction is thought to be the common denominator of ED. Defined as a reduced vasodilation or even paradoxical vasoconstriction in response to endothelium-dependent vasodilatory stimuli, endothelial dysfunction in many circumstances precedes morphological changes of the vessel wall or the formation of atherosclerotic plaques. With injury to the endothelium, the nitric oxide-cyclic guanosine monophosphate axis is impaired, interfering with smooth muscle relaxation and vasodilatation as a response to neural stimulation. Due to the close association of cardiovascular disease and ED, patients with ED should be evaluated as to whether they may suffer from cardiovascular risk factors including hypertension, cardiovascular disease or silent myocardial ischaemia. Increasing awareness of this association should encourage men to discuss their ED with medical practitioners.

Sexual activity as a promoter of health: Sexuality is an essential aspect of normal human function, well-being and quality of life. In fact, several longitudinal studies of varying duration have demonstrated an inverse relationship between sexual activity and risk for death, although their trial designs did not enable determination of the direction of causality. The Duke First Longitudinal Study of Aging, a 25 yr trial involving 270 men and women aged 60-94 yr at study outset, found that the frequency of sexual intercourse was a significant predictor of longevity in men. Conversely, a Swedish study involving 128 married men aged 70 yr followed for 5 yr showed that early cessation of sexual intercourse was associated with an increased risk for death as compared with continuing sexual relation. From a different perspective, the Catholic priests and nuns, who were celibates, offered another epidemiological design. A retrospective cohort analysis involving 10026 priests in the United States revealed the overall standardized mortality ratio (SMR) of 103 and the SMR for cancer of the prostate was 81. A study of nuns found opposite findings, with lower overall mortality than in the general population. The 2,573 Catholic sisters had high rates of mortality from cancers of the breast and reproductive organs, suggesting an effect of nulliparity manifested in older women.

Counselling on sexual activity for patients: It is important for the clinicians to know how to counsel patients on sexual activity and the effects of some pharmacologic therapies. The most important information for counselling is the absolute difference in risk the activity produces. For instance, Framingham Heart Study research indicates that the risk of a 50 yr old non smoking, non diabetic man to experience an MI is 1 per cent per year, or 1 chance in 1 million per hour because the relative risk (RR) of MI is doubled by sexual activity, such an individual will only increase his hourly risk to 2 in 1 million, and only for a 2 h period.

Considering the potential risk of cardiovascular disease associated with sexual activity, the First Princeton Consensus (Princeton I) in 1999 developed guideline for assessment and management of patients with varying degrees of cardiac risk. These guidelines were updated in 2004 (Princeton II) based on new data concerning the link between ED and cardiovascular disease and the new treatments availability. Patients can therefore be risk stratified about safety returning to or continuing sexual activity. The asymptomatic
patients with fewer than three risk factors for CAD, stable angina, recent uncomplicated MI, mild valvular heart disease, mild congestive heart failure (CHF) - New York Heart Association class II, controlled hypertension, or post successful revascularization are considered low risk. Intermediate risk patients would include those with more than three risk factors for CAD, recent MI, moderate CHF, peripheral vascular disease, etc. High risk patients would be those with unstable angina, poorly controlled hypertension, severe CHF (New York Heart Association class III/IV), MI within 2 wk, significant arrhythmias, severe cardiomyopathies, and moderate to severe valvular disease.

Sexual activity remains safe for a large majority of patients. The low risk category includes patients for whom sexual activity does not represent a significant cardiac risk. High risk patients should be referred for cardiologic assessment and treatment. Sexual activity should be deferred until a patient’s cardiac condition has been stabilized by treatment or a decision has been made by a cardiologist that sexual activity may be safely resumed.

Besides safety and drug interaction data for three phosphodiesterase type 5 (PDE5) inhibitors (sildenafil, tadalafil, vardenafil) suggested, lifestyle modification is also important factor as obesity and sedentary lifestyle have been shown as risk factors for ED in a number of cross-sectional and longitudinal studies. Intervening on cardiovascular and lifestyle factors may have broader benefits beyond restoration of erectile function.

**Cardiovascular effect of sexual activity**

*Laboratory research*: BP and HR are the most direct and common variance of cardiovascular indices, used to evaluate the metabolic expenditure in response to sexual activity. Recorded BP and HR values in many studies done before 1970s were much higher, almost near that of maximum exercise, as those were taken in “unnatural” laboratory settings. A small study in 1956 reported that the peak HR was approximately 125 bpm in coitus. With the availability of portable ambulatory BP equipment in 1970s, the results came up quite different from before. The HR obtained by dynamic monitoring device and the BP measured by non-simultaneous monitoring were remarkably lower than the previous reports. There were not more than 100 subjects in each study, either healthy or with cardiac disease from young to middle age (Table II). The researches focused on variances of cardiac responses to sexual activity in different positions or different phases. In general, for most individuals, it appears that sexual activity is similar to mild to moderate intensity exercise. This was true for individuals with or without coronary disease.

The peak HR during intercourse was no significantly higher in relation to the daily life HR for all patients. A study by Hellstein & Friedam showed the mean max HR in orgasm at 117.4 bpm with the equivalent BP at 162/89 mmHg. The ECG changes of the monitored subjects showed that the cardiovascular responses (ST-T segment depression, or ectopic beats and symptoms, or both) during coitus and occupational activities were comparable in frequency and severity. The main findings of this study were: (i) one third of the patients had ischaemia, mostly silent, during intercourse; (ii) all patients with ischaemia at intercourse also had ischaemia during exercise; (iii) patients without

<table>
<thead>
<tr>
<th>Time</th>
<th>Cases</th>
<th>Condition</th>
<th>Age</th>
<th>Peak HR (beats/min)</th>
<th>Peak SBP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>48</td>
<td>Arteriosclerotic disease</td>
<td>middle-aged</td>
<td>117.4</td>
<td>162(M)</td>
</tr>
<tr>
<td>1976</td>
<td>50</td>
<td>Healthy</td>
<td>24-40</td>
<td>114,117</td>
<td>163 (MOT), 161 (MOB)</td>
</tr>
<tr>
<td>1977</td>
<td>49</td>
<td>Post MI</td>
<td>46-54</td>
<td>127,120</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>21</td>
<td>8 with CAD</td>
<td>40-66</td>
<td>119</td>
<td>145</td>
</tr>
<tr>
<td>1980</td>
<td>20</td>
<td>Healthy</td>
<td>20-49</td>
<td>126,120</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>21</td>
<td>Hypertensive</td>
<td>29-56</td>
<td>131 (M), 96 (F)</td>
<td>237/133 (M), 216/127 (F)</td>
</tr>
<tr>
<td>1984</td>
<td>22</td>
<td>Healthy</td>
<td>25-34</td>
<td>127±23</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>47</td>
<td>Stable coronary disease</td>
<td>36-66</td>
<td>118±21</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>54</td>
<td>Healthy</td>
<td>24-55</td>
<td>108, 100</td>
<td>141 (M), 121 (F)</td>
</tr>
<tr>
<td>2007</td>
<td>32</td>
<td>10 with CAD</td>
<td>41-70</td>
<td>113 (M), 136 (F)</td>
<td>152 (M), 136 (F)</td>
</tr>
</tbody>
</table>

MOT, man on top position; MOB, man on bottom position; M, male; F, female; HR, heart rate; SBP, systolic blood pressure; MI, myocardial infarction; CAD, coronary artery disease

Superscript numerals represent Ref. no.
ischaemia at exercise did not have ischaemia during sexual activity; and (iv) ECG findings showed that a greater number of patients had ischaemia during stress test compared with sexual activity. The mean peak HR at exercise was in fact higher than during intercourse. Another study demonstrated mean peak coital HR at 127 bpm before a 16 wk bicycle ergometer-training, 12 to 15 wk following their first MI, and 120 bpm after training programme during coitus. All 16 trained patients showed a significant decline in the measured peak coital HR. It shows clearly the relationship of improved fitness consequent to exercise training and the reduction in peak HR achieved during sexual activity.

In contrast to patients with heart disease, some cardiologists targeted healthy people as their research subjects. Sub-sample studies in healthy men, using ambulatory electrocardiogram during coitus in different position (man-on-top and man-on-bottom position) and different types (self-stimulation, partner stimulation) of sexual activity respectively, also demonstrated the moderate HR and BP, no superior to the maximum rate observed during the day. The results were similar to that achieved in the cardiac patients. The recent all healthy subjects research conducted by Tan and colleagues on 49 normal couples with 24 h Holter ECG and blood examination, added the female data that the previous researches did not provide. Peak coital HR was found to occur at the onset of orgasm phase in both sexes; peak BP occurred at onset of plateau phase instead of orgasm phase. Besides HR, BP, double product recorded, they also observed the changes of plasma endothelin (ET), thromboxane B₂ (TXB₂) and 6-keto-prostaglandin F₁α (6-K-PGF₁α) after sexual activity in healthy adults and found no marked graded changes among them. It is presumed that as a physiological activity, sexuality should have perfect self-regulation mechanism that its physical demand is in the range of daily activity, posing no cardiovascular risk. This is the first clinical research on sexual activity in China, representing data from Asian. HR and BP recorded during the intercourse were either lower than the previous related research, or the latest one by Palmeri et al in America.

Epidemiological study: The case-crossover methods and cohort studies in recent years provided quantitative data on whether sexual activity is a risk factor, offering more reliable evidence (Table III).

<table>
<thead>
<tr>
<th>Time</th>
<th>Study</th>
<th>Interviewees</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>The Caerphilly</td>
<td>914 men*</td>
<td>Cohort study</td>
</tr>
<tr>
<td>1979</td>
<td>The Caerphilly</td>
<td>918 men*</td>
<td>Cohort study</td>
</tr>
<tr>
<td>1989</td>
<td>MIOS</td>
<td>858</td>
<td>Case-crossover analysis</td>
</tr>
<tr>
<td>1993</td>
<td>SHEEP</td>
<td>699</td>
<td>Case-crossover analysis</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>470</td>
<td>Case-crossover analysis</td>
</tr>
</tbody>
</table>

*Subjects are all male

The Caerphilly study was the first one to examine the relation between frequency of sexual intercourse and risk of ischaemic stroke and coronary heart disease (CHD), in Caerphilly, a former mining town in South Wales from 1979-1983. Of the 914 men studied, 197 (21.5%) reported sexual intercourse less often than once a month, 231 (25.3%) reported twice or more a week, and the remaining 486 (53.2%) men fell into the intermediate category. Frequency of sexual intercourse was not associated with all first ischaemic stroke events. Longer follow up to 20 yr showed the risk decrease to 1.69 (95% CI 0.90 to 3.20), contrasting low frequency of sexual intercourse with the highest group. Odds of stroke among men suffering fatal strokes were lower in those reporting intermediate and low levels of sexual intercourse. It is curious that at 10 yr of follow up, fatal CHD events were more than twice as common in those reporting an intermediate or low frequency of sexual intercourse (intermediate frequency age adjusted OR - 2.07, 95% CI 1.09 to 4.08 and low frequency- 2.80, 95% CI 1.12 to 6.96), showing a stronger effect than after 20 yr follow up. It was interesting to note that stroke was more common in those men who did not respond to the question on sexual activity. Perhaps shared the same group of subjects by Myocardial Infarction Onset Study (MIOS) interviewed 918 people, to assess the relation between frequencies of orgasm and mortality. Over 10 yr of follow up 150 of the respondents died: 67 from CHD and 83 from other causes. They found that mortality risk was 50 per cent lower in the group with high orgasmic frequency than in the group with low orgasmic frequency.

Besides these two cohort studies, there were three case-crossover studies in post MI patients conducted by Stockholm Heart Epidemiology Programme (SHEEP).
and the latest study in Costa Rica to assess the risk of sexual activity.

In the Möller study, the RR of MI in the 2 h after sexual activity was 2.5 (95% CI, 1.7 to 3.7). The RR among patients without a history of cardiac disease was 2.5, similar to that among patients with a history of MI (RR of 2.9). Among patients with a history of angina, the RR of sexual activity triggering MI was 2.1, similar to the RR of 2.6 observed among those without angina. The study also found that regular exercise had a significant protective effect and appeared to eliminate the risk of sexual activity. The second case-crossover study found that the RR of MI was 2.1 (95% CI 0.7 to 6.5) during 1 h after sexual activity, and the risk among patients with a sedentary life was 4.4 (95% CI 1.5 to 12.9). The Baylin study reported RR of 5.74 (95% CI, 2.71-11.02) for patients having sexual activity 2 h before MI.

Conclusion

The risk of triggering MI or other heart disease is considered to be quite low if sexual activity is performed with marital partner in a familiar setting, and without heavy meal or drinking. The cardiovascular demand of sexual activity is found to be within normal daily activities. Further, the population-based epidemiologic study revealed that frequent sexual intercourse is not likely to trigger a substantial increase in risk of strokes. On the contrary, the odd of risk is lower in those who have more sexual activity than those having less, and the mortality risk is half per cent lower in the group with high orgasmic frequency than in the group with low orgasmic frequency. It can therefore be concluded that sexual activity is one of the human normal physiological functions, which will contribute to physical health just like walking or other daily activity does. Counselling should focus on encouraging people to have a physical active life and not on abstaining from sexual activity.

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