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Pumping Life into Longevity: External Counterpulsation as a Catalyst for Healthy Ageing

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ABSTRACT

Human ageing is a complex biological process marked by a decline in physiological and functional capacity. As Malaysia faces a rapid demographic shift towards an ageing population, the need for innovative, multidisciplinary approaches to promote healthy ageing becomes increasingly urgent. This review explores the potential role of External Counterpulsation (ECP), a non-invasive mechanical therapy, as a valuable adjunct in healthy ageing strategies. ECP has demonstrated efficacy in improving cardiovascular function, enhancing exercise tolerance, and reducing major adverse cardiovascular events. Its integration into comprehensive ageing frameworks may reduce healthcare burden, enhance functional independence, and support the broader goals of geriatric care, gerontology, and juventology. This paper advocates for a wider adoption of ECP into Malaysia's ageing policy to foster a healthier, more resilient elderly population.

1. Introduction

Human ageing is a complex and multifaceted regressive and degenerative biological process which results in the decline in functional and physiologic capacity [1]. The interdisciplinary study of ageing encompasses several key domains:

i. Geriatrics, which focuses on the clinical care and treatment of older adults.
ii. Gerontology, which examines the biological, psychological, and social aspects of ageing.
iii. Juventology, which explores strategies to delay ageing and extend youthfulness [2-5].

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These disciplines collectively contribute to the broader goal of promoting "healthy ageing". Healthy ageing is a scenario where individuals maintain healthy, independent, and secure lives as they grow older [1,6,7]. The term healthy ageing is frequently used interchangeably with related concepts such as "active ageing," "successful ageing," and "productive ageing" [6]. These concepts highlight the importance of empowering older adults to engage meaningfully in society, challenging the perception that they are a burden to their families or the state [8]. Other pillars of active ageing include security, perceived environment, behavioural characteristics, participation and personal characteristics is beyond the scope of this manuscript and have been thoroughly discussed elsewhere [9].

Malaysia is undergoing a rapid demographic shift towards an ageing population, with the pace of this transition outstripping that of many developed nations by 2045. It is projected that the Malaysian population will grow to around 32 and 45 million in 2030 and 2045, respectively [10]. With these, an approximate of 15.3 and 19.8% of the population would be aged 60 and above in the projected years [11,12].

The rising incidence of non-communicable diseases (NCDs) among older adults, along with the decline of traditional family-based support, has placed greater pressure on healthcare systems, highlighting the urgent need for a comprehensive, multidisciplinary medical care [13]. Other than that, low engagement in recreational physical activities, limited awareness of healthy living, and a high rate of NCDs are interconnected challenges in this population. Furthermore, Abdullah *et al.,* [12] emphasize the importance of establishing integrated care systems that coordinate healthcare delivery across multiple settings, including hospitals, primary care clinics, community health centres, and long-term care facilities. They advocate for regular screenings, strict adherence to medication regimens, and lifestyle modification(s) such as engaging in physical activity, maintaining a balanced diet, avoiding tobacco use, and consuminge alcohol in moderation. These are strategies to significantly promote healthy ageing, the prevention of non-communicable diseases (NCDs), and increased life expectancy [12].

The advancement of digital health technologies presents valuable opportunities to enhance healthcare accessibility and management for the ageing population [14]. Assistive technologies play a vital role in supporting or improving functional abilities in domains such as cognition, communication, hearing, mobility, self-care, rehabilitation, and eyecare. These technologies contribute to improved health outcomes, greater well-being, and increased social inclusion and participation among older adults [15-18].

Over the past decade, there has been a notable surge in ageing-related research in Malaysia [19]. However, to our best knowledge, none has highlighted the available regenerative technologies to address this. In this context, External Counterpulsation (ECP), a non-invasive mechanical therapy has shown promise in managing multiple conditions prevalent among the ageing population. ECP augments the supraphysiologic capacity of the circulatory system by synchronizing external pressure pulses with the cardiac cycle [20]. Studies have demonstrated its efficacy in improving diastolic function, reducing hospital readmissions, and enhancing quality of life in patients with ischaemic heart failure [21,22]. In this review, we will be discussing the role of ECP as a valuable adjunct in healthy ageing.

2. Basic Functional Units and Working Principles of ECP

2.1 Basic Functional Units

ECP therapy consists of three sets of pneumatic cuffs attached to each of the patient's legs at the calves, and both the lower and upper thighs as shown in Figure 1. The inflation of the cuffs is triggered by a computer, and timing of the inflation is based on the electrocardiogram (ECG). Some examples of the available ECP devices in Malaysia are depicted in Figure 2.

Fig. 1. The ECP pneumatic cuffs placement on a subject

Fig. 2. Some of the available ECP devices in Malaysia. A and B are older versions of the device with an analogue interface while C and D have touch screens or laptop-based operation
*Device images courtesy of Dr Freddy Maung Maung, Dr Rosmawati Mohamed and Dr Shah Reza Khelikuzaman

2.2 Working Principle of ECP

The working principle and biomedical goal of ECP is to augment the diastolic phase sufficiently to cause retrograde arterial blood flow, increase venous return, increase cardiac output, and to allow beneficial arterial shear injury [20,23,24]. These are achieved via the following:

i. A sequential inflation and deflation of the three cuffs placed over the calves, thighs and buttocks (counterpulsates from caudal to cranial).
ii. The ECP therapist adjusts the inflation and deflation timing to provide optimal diastolic augmentation by monitoring the pulse plethysmogram (PPG) waveform reading (integrated within the ECP device). The PPG and the representation of the arterial waveform is shown in Figure 3.
iii. A pressure of 100–300 mmHg is sequentially applied from caudal to cranial direction resulting retrograde aortic and peak diastolic pressure.
iv. The pressurized air is quickly exhausted from the cuffs at the completion of diastole and the beginning of systole. The changes of the arterial waveform in relation to the ECG is depicted in Figure 4.
v. The process repeats in accordance with the cardiac cycle over the course of a 60-minute session
vi. Typically, the protocol in various studies worldwide is done 10-35 individual sessions but may be subject to clinical indication and discretion [25,26].

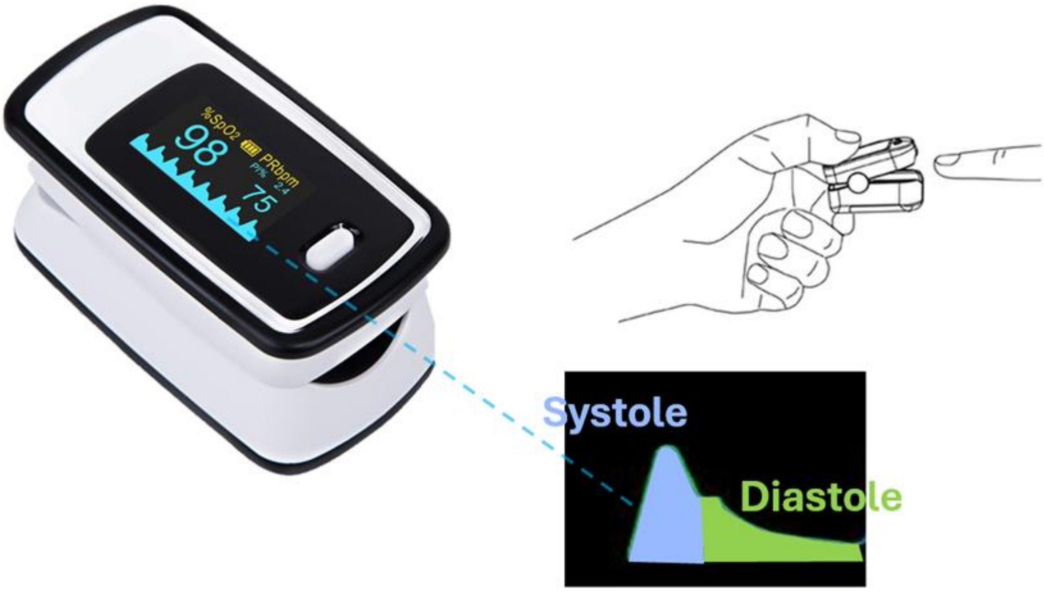

Fig. 3. PPG and arterial waveform in a steady (non-conterpulsation state)

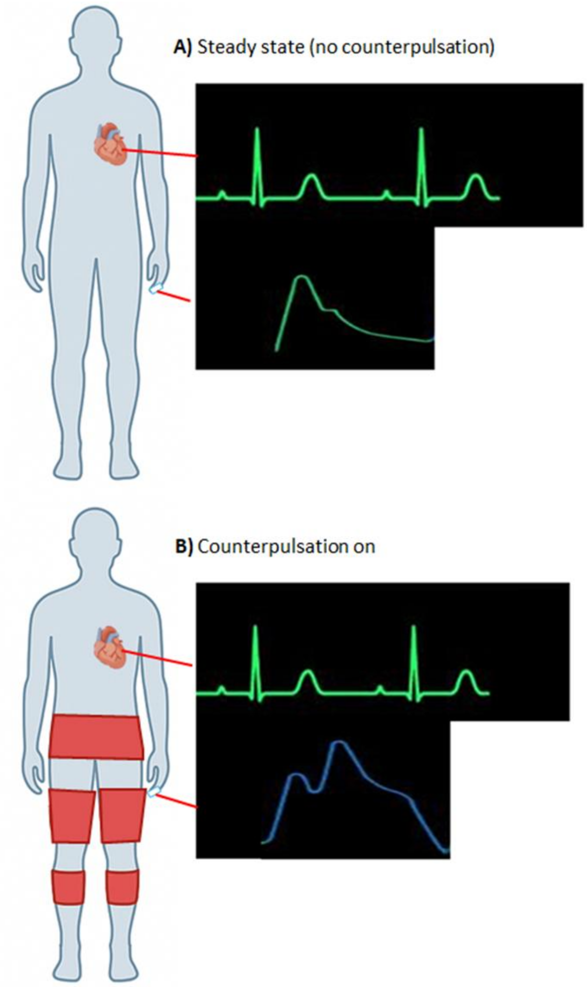

Fig. 4. The ECG and PPG signals during no counterpulsation (A) and upon counterpulsation (B). The diastolic augmentation (shown in blue) of the PPG signal is depicted in (B)

3. Basic Sciences of ECP

3.1 Physiologic Changes with ECP

The current knowledge on ECP is backed by several mechanisms including increase venous return, increase shear stress on endothelium, systolic unloading, and diastolic augmentation [27,28]. Figure 5 shows the arterial waveform form of a PPG upon steady state, optimal counterpulsation, and immediately after counterpulsation.

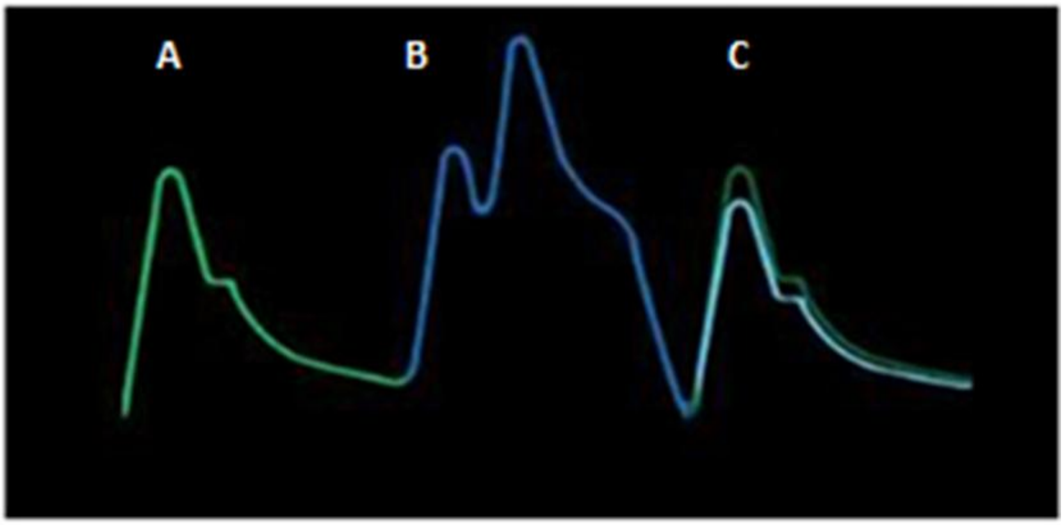

Fig. 5. Arterial waveform upon (A) steady state/ no counterpulsation, (B) upon optimal counterpulsation and (C) immediately after counterpulsation. Note that the systolic peak of wave (C) is reduced compared to (A) and (B)

These result in both cardiac (local) and peripheral (systemic) effects, namely increased cardiac output, increased coronary perfusion, enhanced collateral capillary sprouting, vasodilatation, increase plasma and platelet guanosine monophosphate (cGMP), increase fractional flow reserve (FFR), and increase Cluster of Differentiation 34 (CD 34+) and CD 133+ [27,29].

3.2 Collateralization Effect with ECP

Zimarino *et al.,* [30] concluded that the coronary collateral circulation protects the heart from myocardial ischaemia and is associated with improved survival in patients with coronary artery disease. Few important highlights from the authors were:

i. Collateral vessels are present at birth and develop throughout life
ii. These collaterals undergo positive remodelling (arteriogenesis) in the presence of a total or subtotal coronary occlusion, and usually regress with age
iii. The myocardial protective effect of the collateral circulation is dynamic in nature.

Preconditioning, the injection of growth factors (such as the α-actin, von Wilebrand Factor(vWF), vascular endothelial growth factor (VEGF), basic fibroblast growth factor (BFGF) and hepatocyte growth factor (HGF)), and strategies to prolong ventricular diastolic filling time (as exerted by the ECP) all promote collateral vessel growth and remodelling [23,27,29].

3.3 Increased Myocardial Perfusion

A meta-analysis and systematic review of six studies with ECP therapy implied that the myocardial perfusion in coronary artery disease patients increased significantly with no evidence of publication bias [23]. A single study from the meta-analysis showed increased coronary flow velocity of 150% post ECP as it promotes vasodilation and angiogenesis [23].

3.4 Increased Flow and Perfusion to Other Vessels

Other than the coronary artery and the aorta, the counterpulsation also increases the flow and stroke volume to most major vessels. These are depicted in Figure 6.

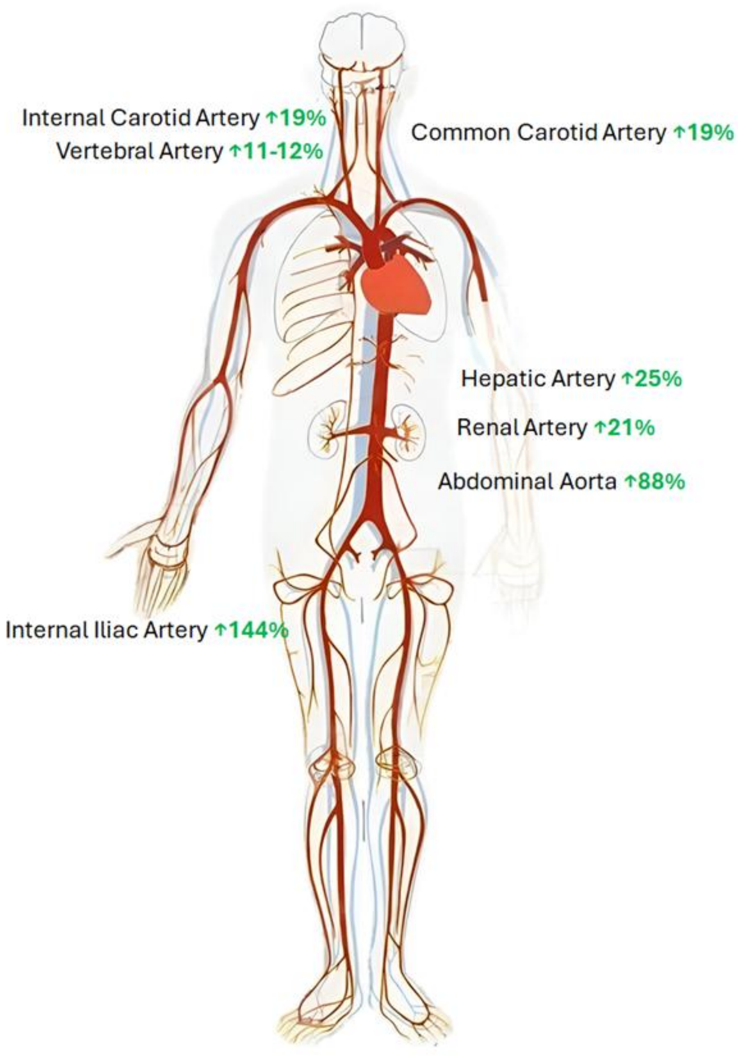

Fig. 6. Flow and volume increment by percentage upon counterpulsation. *Modified from Ramasamy [24]

4. Healthy Ageing Integration of ECP

4.1 Clinical Indication, Contraindication, and Protocol

The indication and contraindication for an individual to undergo ECP needs to be considered prior to initialising the therapy. The ECP could be utilised for both cardiac and non-cardiac conditions. Our research group has previously developed an extensive clinical protocol paper for the ECP therapy, and this has been published elsewhere [20]. The ECP could be utilised for primary prevention, curative, rehabilitative, and even resuscitation means [20].

4.2 Potential Healthy Ageing Integration

The prevention of disease and disability in older adults is most effective when health-promoting behaviours are adopted early in life and sustained throughout the lifespan [32]. Individuals who maintain a healthy lifestyle are more likely to experience a higher quality of life in old age. Therefore, primary prevention should target all age groups, not solely the elderly, to establish a strong foundation for healthy ageing [32].

In this context, ECP may serve as a preventive adjunct in individuals at risk of NCDs, even before clinical symptoms emerge. While traditionally used in symptomatic patients, latest evidence suggests that ECP may improve vascular function and perfusion, potentially delaying the onset of conditions related to endothelial dysfunction [33–35].

Otherwise, ECP plays a rehabilitative role by enhancing cardiac performance, increasing exercise tolerance, and reducing the incidence of major adverse cardiovascular events [36,37]. Another important aspect of healthy ageing is the contribution of ECP to improved sleep quality, along with its beneficial effects in alleviating symptoms of anxiety and depression [36]. The ECP therapy has also shown potential favourable outcomes in long-COVID and lung fibrosis, which the ageing population is more susceptible to [38,39]. Figure 7 shows the collated benefits of ECP in healthy ageing.

Fig. 7. The collated evidence of the role of ECP in healthy ageing

When integrated into comprehensive rehabilitation programmes, ECP can support functional recovery and promote independence in daily living. From a healthcare financial perspective, ECP offers a non-invasive, low-risk intervention at a low to moderate cost. Other than that, it could also play a role by reducing hospital admission and promoting the regenerative capacity of an aged individual thus promoting juventology.

4. Conclusions

Given the non-invasive nature, operational simplicity, and global accessibility of ECP, we advocate for its broader adoption for healthy ageing purposes. By integrating ECP into healthy ageing strategies, Malaysia can leverage this technology to support cardiovascular health in older adults, reduce the burden on acute care services, and promote functional independence. This aligns with the broader goal of achieving a healthy ageing society—one that upholds dignity, encourages active participation, and fosters a cultural shift in societal attitudes toward ageing. Achieving this vision requires a collective commitment to innovation, compassion, and inclusive policymaking, ultimately benefiting both the elderly and the nation's overall well-being. In this instance, the ECP is an elegant biomedical device that deserves more respect.

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