Autonomic Neuroscience: Basic and Clinical 189 (2015) 56–59

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

journal homepage: www.elsevier.com/locate/autneu

Effects of trunk posture in Fowler's position on hemodynamics

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ARTICLE INFO

Article history:
Received 16 April 2014
Received in revised form 10 October 2014
Accepted 6 January 2015

Keywords:
Cardiovascular regulation
Impedance cardiography
Systolic time intervals

ABSTRACT

We speculated that stroke volume would be higher and heart rate would be lower when the head and upper trunk were mainly upright in the Fowler's position. We therefore analyzed the effects of three trunk postures in Fowler's position on heart rate, blood pressure and circulatory volume.

Heart rate (HR), blood pressure (BP), stroke volume (SV), cardiac output (Q), systemic vascular resistance (SVR), ejection time (ET) and pre-ejection period (PEP) were measured in 10 healthy male volunteers (mean age ± SEM, 20.7 ± 0.5 y; range, 19–23 y) while in three trunk postures in Fowler's position. Stroke volume and Q were measured using impedance cardiography. The three trunk postures were 30° of lower and upper trunk inclination (WT30°), 30° and 60° of lower and upper trunk inclination (UT 60°), respectively and 60° of upper and lower trunk inclination (WT60°).

Both SV and ET were significantly higher and HR and PEP were lower at UT60° than at WT60° ($p < 0.01$) whereas these values did not significantly differ between WT30° and UT60° ($p > 0.05$). None of Q, SVR and BP significantly differed among the three conditions ($p > 0.05$).

These findings suggested that SV and preload are higher when the upper trunk is upright (UT60°) than when the entire trunk is upright (WT60°) while in Fowler's position. In addition, Q might be maintained without increasing HR through vagal withdrawal when only the upper trunk is upright in healthy young males in Fowler's position.

1. Introduction

Studies of cardiovascular regulation in humans with the head tilted up (HUT) and down (HDT) have found that posture influences hemodynamics and the autonomic nervous system. Standing or HUT decreases ventricular filling pressure and stroke volume (SV) according to a shift in the distribution of blood volume to the lower extremities. Consequently, sympathetic nerve activity is activated, heart rate (HR) increases and vascular contraction maintains circulatory volume. Conversely, SV increases, sympathetic nerve activity and HR decrease and vagal nerve activity increases in the supine, compared with an upright position (Pagani et al., 1986; Pomeranz et al., 1985; Rowell, 1993; Saul et al., 1991; Shoemaker et al., 2001). These findings were determined by analyzing heart rate and blood pressure fluctuations, circulatory volume, systolic time intervals and muscle sympathetic nerve activity (Pagani et al., 1986; Rowell, 1993; Saul et al., 1991; Shoemaker et al., 2001).

Fowler's position or the semi-seated position is often clinically applied as well as standing and supine positions. Fowler's position is achieved by inclining the backrest of a bed upwards from the supine position with flexed or straight knees unlike HUT and HDT which the whole body is inclined (Potter, 2009). The upright head and trunk in Fowler's position are more essential for the quality of life of patients who are confined to bed or frail and it is clinically applied most frequently at inclinations between 30° and 60° (Carol et al., 2008; Potter, 2009). Patients who are confined to bed or frail are frequently placed in Fowler's position instead of remaining supine to assist ambulation, monitor hemodynamics and facilitate breathing as well as routine activities such as eating or conversation (Carol et al., 2008; Her and Frost, 1999; Metzler and Harr, 1996; Potter, 2009; Rauen et al., 2009). On the other hand, such patients develop orthostatic hypotension because they cannot physically compensate quickly for the downward fluid shift caused by assuming an upright position (Bundgaard-Nielsen et al., 2009; Cowie et al., 2004; Metzler and Harr, 1996; Steinberg, 1980). Thus, to understand the most effective posture required to counteract the downward fluid shift while in Fowler's position should be clinically meaningful. Some studies have described a relationship between the angle of Fowler's position and the accuracy of hemodynamic measurements among patients in intensive care units (Driscoll et al., 1995; Shih, 1999; Wilson et al., 1996) and Driscoll et al. (1995) reported

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http://dx.doi.org/10.1016/j.autneu.2015.01.002

that cardiac output is decreased in patients under intensive care who are in the Fowler's position, compared with those who are supine. A study of young healthy individuals has shown that blood pressure in Fowler's position is intermediate between the seated and supine positions (Cicolini et al., 2010) and a cross-sectional study of hypertensive patients found the same tendency (Cicolini et al., 2011). However, the most appropriate posture required to counteract the downward fluid shift while in Fowler's position has not been investigated as far as we can ascertain.

We speculated that stroke volume would be higher and heart rate would be lower when the head and upper trunk are mainly upright compared with when the head and the whole trunk are upright in Fowler's position, because most body segment positions remain lower when the head and upper trunk are upright. We tested this hypothesis in a fundamental study of the effects of three trunk postures in Fowler's position on heart rate, blood pressure and circulatory volume in healthy young men.

2. Methods

2.1. Study participants

We assessed hemodynamics in 10 male university students (mean age ± SEM, 20.7 ± 0.5 y; range, 19–23 y; weight, 56.7 ± 1.2 kg; height, 170.6 ± 1.5 cm). All were free of chronic or acute cardiovascular, respiratory or other chronic diseases. Beverages containing caffeine or alcohol were not consumed for 24 h before starting the study. All participants refrained from eating and drinking after 2200 h on the evening before the experiments that started in the morning or consumed a light breakfast before experiments that proceeded in the afternoon. All participants were clothed only in shorts.

All experiments were implemented between 1100 and 1400 h. The Ethics Commission of the International University of Health and Welfare approved the study and all recruits provided voluntary written consent to participate after being fully informed about the procedure, risks and protocol.

2.2. Procedure

The participants rested in a thermoneutral room at 28 °C for 15 min and were then prepared for electrocardiography (ECG), continuous measurements of arterial blood pressure and impedance cardiography (ICG). After 5 min resting, data were recorded for 5 min under each condition in all experiments.

The participants were placed in Fowler's positions on a bed at 30° of whole trunk inclination (WT30°), 30° of lower trunk inclination and 60° of upper trunk inclination (UT60°) and 60° of whole trunk inclination (WT60°) (Fig. 1). The upper and lower segments at UT60° were defined by the spinous process of the 10th thoracic vertebra. The height of the bottom of the upper and lower trunk was adjusted according to individual trunk size. All seated positions allowed slight hip and knee joint flexion. All analyses proceeded randomly and were repeated three times in all positions on the same day.

2.3. Instrumentation

Continuous arterial blood pressure was measured at the radial artery by tonometry using a noninvasive arterial blood pressure monitor at the level of the heart. Continuous arterial blood pressure was calibrated using oscillometric sphygmomanometry to measure intermittent cuff blood pressure. Eight Vitrode M spot electrodes (Nihon Kohden, Tokyo, Japan) were attached to the neck and lower thorax of each participant for ICG based on a previous study (Bernstein and Lemmens, 2005). Data from an ECG 100C electrocardiographic lead II (BIOPAC Systems, Goleta, CA, USA) and from impedance cardiography using a NICO 100C instrument (BIOPAC) as well as continuous arterial blood pressure measured using a BP-608EV (Omron Colin, Tokyo, Japan) were recorded on a personal computer using the MP150 data acquisition system (BIOPAC) at a sampling rate of 1 kHz throughout all experiments.

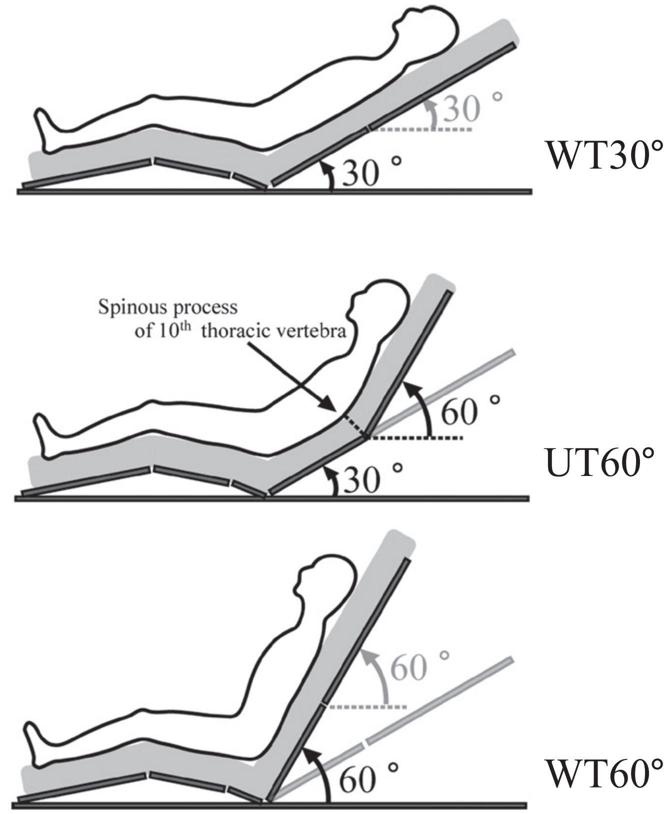

Fig. 1. Bed positions for each condition. A. Lower and upper trunk inclined at 30° (WT30°). B. Lower and upper trunk inclined at 30° and 60°, respectively (UT60°). Upper and lower segments were subdivided based on the spinous process of 10th thoracic vertebra. C. Lower and upper trunk inclined at 60°, respectively (WT60°).

2.4. Data analysis

Heart rate was determined from ECG data in all experiments. Systolic (SBP) and diastolic (DBP) blood pressure was determined from continuous arterial blood pressure. Mean blood pressure (MBP) was calculated as [1/3(SBP − DBP) + DBP)].

We assessed SV, stroke index (SI), cardiac output (Q), cardiac index (CI) and systemic vascular resistance (SVR) using ICG that calculates SV based on thoracic bioimpedance as described (Bernstein and Lemmens, 2005). Q was calculated from product result of SV and HR. Both SI and CI were normalized by SV and Q for the body surface area of each participant (SI = SV/body surface area; CI = Q/body surface area) and SVR was calculated as 80 MBP/Q. Five-minute means of all values were calculated.

We determined the pre-ejection period (PEP) and left ventricular ejection time (ET) from the ECG findings and the derivative signal of ICG for systolic interval analysis (Cybulski, 2011). The PEP was determined as the interval between the Q waves on ECG to point B which is associated with opening of the aortic valve at the first derivative thoracic bioimpedance. Ejection time was determined as the time from point B to point X which is associated with closure of the aortic valve at the first derivative thoracic bioimpedance.

2.5. Statistical analysis

We determined the effects of three postures in Fowler's position upon physiological variables using a repeated measures multivariate