A review of fluid-structure interaction simulation for patients with sleep related breathing disorders with obstructive sleep

W.M. Faizal a, b, N.N.N. Ghazali b, c, Irfan Anjum Badruddin c, d, M.Z. Zainon b, Aznijar Ahmad Yazid b, Mohamad Azlin Bin Ali b, C.Y. Khor d, Norliza Binti Ibrahim d, Roziana M. Razi e

a Department of Mechanical Engineering Technology, Faculty of Engineering Technology, University Malaysia Perlis, 02100 Padang Besar, Perlis, Malaysia
b Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
c Dept. of Mechanical Engineering, College of Engineering, King Khalid University, PO Box 394, Abha 61421, Kingdom of Saudi Arabia
d Department of Oral & Maxillofacial Clinical Science, Faculty of Dentistry, University of Malaya, 50603, Kuala Lumpur, Malaysia
e Department of Paediatric Dentistry and Orthodontics, Faculty of Dentistry, University of Malaya, 50603, Kuala Lumpur, Malaysia

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A B S T R A C T

Obstructive sleep apnea is one of the most common breathing disorders. Undiagnosed sleep apnea is a hidden health crisis to the patient and it could raise the risk of heart diseases, high blood pressure, depression and diabetes. The throat muscle (i.e., tongue and soft palate) relaxes and causes the blockage of the airway and causes the blockage of the airway in breathing. To understand this phenomenon computational fluid dynamics method has emerged as a handy tool to conduct the modeling and analysis of airflow characteristics. The comprehensive fluid-structure interaction method provides the realistic visualization of the airflow and interaction with the throat muscle. Thus, this paper reviews the scientific work related to the fluid-structure interaction (FSI) for the evaluation of obstructive sleep apnea, using computational techniques. In total 102 articles were analyzed, each article was evaluated based on the elements related with fluid-structure interaction of sleep apnea via computational techniques. In this review, the significance of FSI for the evaluation of obstructive sleep apnea has been critically examined. Then the flow properties, boundary conditions and validation of the model are given due consideration to present a broad perspective of CFD being applied to study sleep apnea. Finally, the challenges of FSI simulation methods are also highlighted in this article.

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1. Introduction

Sleep is one of the human biological functions [1,2], which plays the major roles in conversation [2], energy [3], recovery [4] and survival [5] in the daily life. Therefore, good quality of sleep is essential to get the healthy [6] and sound life [7]. Lack of sleep [8] is a critical problem that suffered by millions of people, as one can always hear people complaining about inadequate sleep. Moreover, sleep related breathing disorders lead to considerable morbidity, rise of health care costs, and reduces in quality of life. Particularly, patients with sleep related breathing disorders with Obstructive Sleep Apnea (OSA) is in high-risk groups of other diseases [9]. For example, obesity or overweight [10], hypertension [11], cardiovascular (commonly involved blocked blood vessels) and metabolic disease [12] and cognitive dysfunction (brain fog) [13]. Sleep apnea also gives the negative impact on work efficiency and productivity. Thus, the cost-effective use of health care resources [14] for the milder OSA’s patient is to undergo the treatment (such as lifestyle changes, therapies and continuous positive airway pressure device). The surgical will be considered if the treatment is not effective for the patient.

OSA occurs due to the temporary obstructions in the airway [15] during sleep. The obstructions block the air flow normally in breathing. Several obstructions can be due to collapse, excessively bulky or laxity of the airway tissues (i.e., soft palate and uvula) that blocked the airway and lead to hypopnea or apnea [16]. Generally, the relaxation of throat muscle and gravity effect allows the soft tissues and tongue fall back to the throat area. The thick fatty tissue in the neck may predispose the blockage in the upper airway, which lead to the partial obstruction and snoring and breathing pauses during sleep. The severity of OSA is determined by the number of occurrences by every hour of sleep. Apnea-Hypopneas