CHAPTER

3

DETECTION OF BROWN ADIPOSE TISSUE USING INFRARED THERMAL IMAGING

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3.1 INTRODUCTION

The brown adipose tissue (BAT) was previously thought to have little or no function in the human body. In the late 2000s, BAT was rediscovered, and research has been focused on the manipulation of non-shivering thermogenesis (NST) exerted by BAT (Cannon & Nedergaard, 2004; Saito et al., 2009; van Marken Lichtenbelt et al., 2009; Virtanen et al., 2009). As NST can be influenced by cold exposure, food intake, and certain metabolites, it results in increased warmth of the skin over the activated BAT compared to other sites (Bel et al., 2021; O'Mara et al., 2020; Thuzar et al., 2019). In overweight, aged, and obese adults, BAT is low to almost non-existent, and its presence is inversely proportional to the occurrence of metabolic diseases such as diabetes mellitus, hypertension, and obesity (Cypess & Kahn, 2010; Zhang et al., 2024).

Typically, BAT is quantified through positron emission tomography (PET) with 2-deoxy-2-[fluorine-18] fluoro-D-glucose (^{18}FDG) radionuclide (Almuhaideb et al., 2011; Chakraborty et al., 2015). As reported in numerous studies, infrared thermal imaging (IRTI) can be an alternative to determining BAT (Gatidis et al., 2016; Jang et al., 2014; Law, Morris et al., 2018). The physiologic phenomenon of NST and the anatomical locations of the BAT have been scientifically exploited to suit the principles of IRTI (Lee et al., 2011; Leitner et al., 2017).

This chapter is organised by first presenting the related work in Section 3.2, followed by Section 3.3, which describes the methodology for the image processing techniques and other calculations used to obtain the BAT thermometric parameters. Section 3.4 discusses the results obtained, and finally, Section 3.5 of this chapter provides the conclusions drawn from the study.

3.2 BROWN ADIPOSE TISSUE AND THERMOMETRY USING IMAGE PROCESSING

The related works involve quantifying techniques for BAT, IRTI, and the image processing technique for BAT thermometry.

3.2.1 Quantifying Techniques for Brown Adipose Tissue

The gold standard for measuring the BAT is by using the ^{18}FDG-PET scan. However, this modality is invasive and requires radiotracers (Bos et al., 2019). On the other hand, IRTI offers a safe, low-cost, and non-invasive option for both clinical and research use compared to the ^{18}FDG-PET scan (Law, Morris et al., 2018). Notably, the IRTI of the supraclavicular (SPCV) needs special protocols and procedures prior to the imaging process, such as the 'cold challenge' that would activate the BAT for visualisation. Recently, this protocol has even been proven feasible even in the infant population (Oyama et al., 2021).

The peak infrared (IR) emission wavelength of human skin is approximately 11 μm (Sanchez-Marin et al., 2009). The skin emission wavelengths range from 2 μm to 15 μm, with a constant emissivity of 0.96–0.98 (Steketee, 1973; Ring & Ammer, 2012; Togawa, 1989). Upon 'cold challenge', temperature difference can be detected as early as 85 seconds (Lahiri et al., 2012). In addition, the temperature changes in the SPCV and its relation to non-BAT areas could be rapidly sampled via IRTI, as previously reported by several studies (Haq et al., 2017; Law, Chalmers, et al., 2018; Robinson et al., 2014).

The BAT can be found in adults at the SPCV, mediastinum, axilla, paravertebral, perirenal area, heart, and epicardial coronary arteries (Leitner et al., 2017; Sacks & Symonds, 2013). Moreover, almost 70% of the BAT are located at the SPCV (Leitner et al., 2017). The deep cervical muscles, *masculus* longus colli, sternocleidomastoid, and scalene muscles may also exhibit ^{18}FDG uptake upon cold exposure, as reported in separate studies (Blondin et al., 2015; Hanssen et al., 2015). Hence, these areas may also contribute to the heat captured by the IRTI at the neck area. All these factors make the SPCV a promising site for quantifying BAT activity via IRTI. Table 3.1 depicts the comparison between the known BAT measurement modalities.

Table 3.1 Comparison of brown adipose tissue measurement modalities

Modality	Principle	Advantages	Disadvantages
Ultrasound (contrast enhanced)	Blood flow	- Low cost, easily available, no radiation. - Non invasive - Short measurement time - Portable - Excellent resolution (0.1–1 mm)	- Unable to delineate deeper anatomical BAT below bony structures/ Unable to distinguish between BAW and WAT without Doppler nor contrast enhancement. - Operator and patient dependent. - Not suitable during circulation problem or obese patients. - High chances of bias in results
CT-Scan	Anatomical overlay (BAT density)	- Gives good anatomical delineation of fats	- Radiation - Invasive - Unable to distinguish WAT and BAT

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