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Review

Visceral adiposity index as a predictor for type 2 diabetes mellitus in Asian population: A systematic review

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ABSTRACT

Background: Visceral Adiposity Index (VAI) is a formula to estimate visceral fat accumulation which has been reported to have a better prediction for type 2 diabetes mellitus (T2DM) in Caucasian population. This systematic review is proposed to inquire whether VAI can be used as a predictor of T2DM in Asian population with different body composition compared to the Caucasian.
Methods: All studies performed in Asia and published in English on VAI prediction on the incidence of T2DM were included. The search keywords used in Pubmed and Cochrane database were visceral adiposity index, VAI and T2DM.
Results: Seven included studies, of which six studies were conducted in China and one in Iran. Four studies were prospective cohorts and the other three were cross-sectional. The largest study population were 7639 subjects, while the longest observation period was 15 years. This study found that VAI can be used as a predictor of T2DM in Asian population with better prediction values compared to Caucasian population. The reported odds ratio or hazard ratio ranged from 1.2 to 3.6.
Conclusions: VAI is a practical formula used to estimate the accumulation of visceral fat which can be used as a predictor for T2DM in Asian population.

1. Background

In the past few decades, the prevalence of type 2 diabetes mellitus (T2DM) has been increasing worldwide [1]. WHO reported that the global prevalence of T2DM has doubled from 4.7% to 8.5% [2]. This increase was caused by the changes in lifestyle towards sedentary lifestyle with consumption of high-calorie diet [1]. This risky lifestyle will cause positive energy balance and obesity, an important risk factor in the pathogenesis of T2DM [3,4].

Most epidemiological studies use Body Mass Index (BMI) and waist circumference as a parameter to diagnose obesity. However, BMI cannot differentiate between fat mass and muscle mass. While the measurement of waist circumference is used to detect central obesity, it cannot differentiate between visceral and subcutaneous fat [5–7]. Inner body fat consisted of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), of which VAT played a relatively more important role in the pathogenesis of T2DM. T2DM patients have more VAT compared to non-diabetic patients [8]. Studies have shown that Asian had a higher VAT and higher proportion of T2DM compared to American and African American women despite having a lower BMI and waist circumference [9]. These findings indicated that VAT evaluation is essential to determine the risk of T2DM.

VAT evaluation can be carried out using abdominal CT scan or MRI. However, such examinations are quite expensive and are still limited, and therefore difficult to be applied for population-based studies or in clinics [5]. Visceral adiposity index (VAI) is a mathematical model (Fig. 1) to estimate VAT using anthropometric and laboratory parameters by calculating linear equation of body fat distribution and corrected by high-density lipoprotein cholesterol (HDL-C) and triglyceride level [10,11]. VAI has been reported to have a positive correlation with the surface area and volume of VAT,

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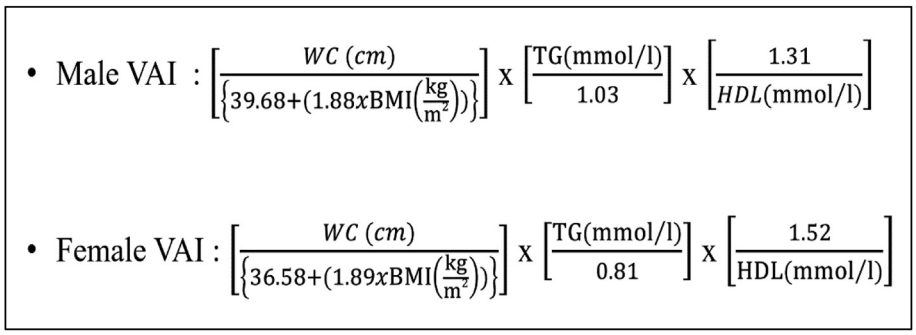

Fig. 1. Visceral adiposity index formula.
VAI: Visceral Adipose Index, WC: Waist Circumference, BMI: Body Mass Index, TG: Triglyceride, HDL: High-Density Lipoprotein.

and with insulin resistance, an important pathogenesis in the development of T2DM [10]. However, this VAI calculation was developed from Caucasian population. Therefore, its applicability in Asian population, which generally has higher VAT despite having a smaller body figure, must be further evaluated. This systematic review aims to inquire whether VAI can be used as T2DM predictor in Asian population.

2. Method

This systematic review was conducted using the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) standard [12]. The inclusion criteria were studies which analyzed VAI as a predictor for T2DM in Asian population, cross-sectional or cohort studies and studies that were published within the past 5 years. There was no limitation in sample size and minimum observation period. This systematic review has been registered on The International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42018109144).

The search was conducted in July 2018 using 2 databases: Pubmed® and Cochrane Central Trial Database - EMBASE®. The search strategy in Pubmed used keywords such as: ((diabetes[Title/Abstract]) OR prediabetes[Title/Abstract]) AND visceral adiposity index[Title/Abstract]. While the literature search in Cochrane Central Trial Database-EMBASE used keywords such as: VAI in Title Abstract Keyword OR Visceral adiposity index in Title Abstract Keyword AND diabetes mellitus type 2 in Title Abstract Keyword AND predictor in Title Abstract Keyword. Studies were limited to human subjects with available complete article and published in English.

The study selection was conducted by two reviewers (RN and DLT). After the initial screening, both reviewers evaluated the studies separately to analyse its eligibility. The chosen articles were critically reviewed using the Newcastle Ottawa Scale (NOS) [13]. Studies that received NOS score of 7 or more was considered to be high-quality studies. RN and DLT independently recorded the chosen study data. The data extracted consisted of: study citations (author, title of journal, year of publication), study characteristics (country, study design, sample size, study setting and period of observation) and the results of each study by recording the odds ratio/hazard ratio values.

3. Results

The process of searching and selecting the studies was presented in Fig. 2 which yielded a total of 62 articles. Only nine studies were suitable to answer the study question [14–22]. After analysing the eligibility criteria, two studies were excluded as they did not meet the study criteria. The study by Kavaric et al. was excluded due to the subjects were Caucasians and the study by Bozorgmanesh et al. was excluded because it was published over five years period [20,21].

Seven articles included in this study were summarized in Table 1. All studies were observational studies conducted in adult population. Almost all included studies were held in China [14–18,22] with one study conducted in Iran [19]. Four out of seven studies were prospective cohorts and the three others were cross-sectional studies. The largest study population were 7639 subjects while the longest observation period was 15 years. All included studies compared VAI with other anthropometric parameters as T2DM predictor.

A study by Gu, Liu et al. and Wang et al. reported VAI as an independent predictor of T2DM in adult population with odds ratio (OR) of 2.305 (95% CI 1.623–3.273), 2.176 (CI 95%1.404–3.374) and 1.538 (95% CI: 1.225–1.930), respectively. A study by Du et al. showed that in male, VAI was an independent predictor of T2DM with adjusted OR (ORadj) for second, third and fourth VAI quartile of 1.1 (95% CI 0.7–1.7), 1.9 (95% CI 1.3–2.8) and 3.6 (95% CI 2.5–5.3) respectively. Meanwhile, in female, they reported adjusted OR of 0.9 (95% CI 0.5–1.4), 1.7 (95% CI 1.1–2.6), and 2.8 (95% CI 1.9–4.2), for second, third and fourth quartile of VAI respectively [14,15,17,18]

Other studies in China by Chen et al. in 2014 and Zhang et al., in 2016 also showed significant results with the adjusted hazard ratio (HRadj) of 1.75 (1.05–2.92) and 2.21 (1.35–3.61) for the third and fourth tertile of VAI respectively. Study by Zhang et al. also reported the HRadj for third tertile of VAI for men and women of 2.854 (95% CI 1.815–4.487) and 3.351 (95% CI 1.586–7.955) respectively [16,22]. Similarly, a study by Janghorbani in Iran also reported that VAI was an independent predictor for T2DM with ORadj of 1.5 (95% CI 0.9–2.49), 1.86 (95% CI 1.18–3.08) and 1.99 (95% CI 1.22–3.25) for third, fourth, and fifth quartiles of VAI respectively [19].

The analysis on the chosen study subgroups compared VAI with other related parameters in order to predict T2DM incidence. However, the comparison between VAI and waist circumference as the T2DM predictor yielded different results among the included studies. A study by Liu et al., in 2016 showed a better predictive value of VAI compared to waist circumference in female population (AUC male population 0.617 vs. 0.601 and in female population 0.762 vs. 0.663) [14]. Similar results were reported in a study by Chen et al., in 2014 [AUC 0.62 (0.58–0.66) vs. 0.55 (0.51–0.6) $p < 0.001$] [16]. However, Janghorbani et al., Wang et al. and Zhang et al. reported that the AUC of VAI was not superior compared to

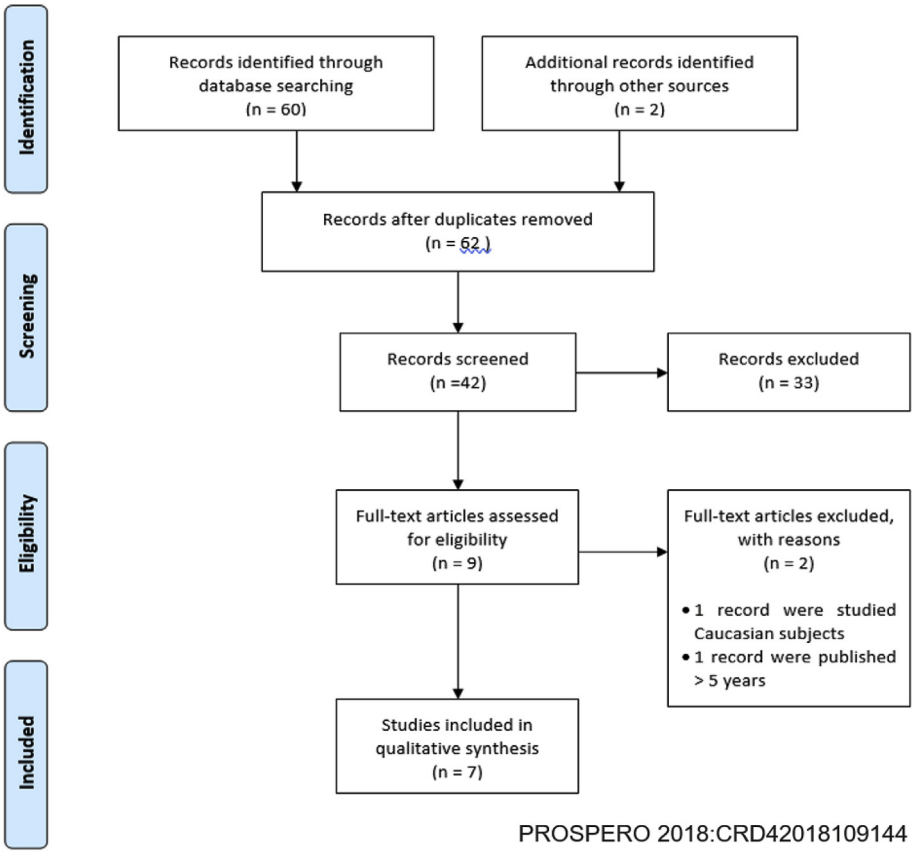

Fig. 2. Search strategy.

Table 1
Description of selected studies.

No	Author	Years	Location (Total subjects)	Design (Observation time)	Results
1.	Liu et al. [14]	2016	China (2754)	Cross Sectional	**Male**: 3rd tertil ORadj 2.176 (95% CI 1.404–3.374) p < 0.001), **Female**: 3rd tertil ORadj 7,63 (95% CI 2.502–23.268) p < 0,001. **AUC VAI vs WC** (Male 0.617 Vs 0.601, and female: 0.762 VS 0.663)
2.	Gu, D [17]	2017	China (5457)	Cross Sectional	**Male**: OR 1.641 (95%CI 1.146–2.349); p: 0.007; **Female**: OR 2.305 (95 %CI 1.623–3.273); p:0.009. **AUC VAI vs WC** (Male: 0.633 vs 0.648, and female: 0.730 vs 0.733)
3.	Wang et al. [18]	2015	China (687)	Prospective Cohort (15 years)	Each SD increment in log VAI, the risk of diabetes increased by 53.8% (HR: 1.538, 95% CI: 1.225 –1.930). Paired homogeneity test VAI p:0.16.
4.	Du, T [15]	2014	China (7639)	Cross Sectional	**Male**: Oradj, 2nd Quartile 2 1.1 (95% CI 0.7–1.7), 3rd quartile 1.9 (95% CI 1.3–2.8) dan 4th quartile 3.6 (95% CI 2.5–5.3) p < 0.05. **Female**:3rd quartile 1.7 (95% CI 1.1–2.6) and 4th quatile 2.8 (95% CI 1.9–4.2) p < 0.05.
5.	Chen et al. [16]	2014	Cina (4631)	Prospective Cohort (5–10 years)	HRadj 2nd quartile 1.22 (95% CI 0.71–2.11), 3rd quartile 1.75 (95% CI 1.05–2.92), 4th quartile 2.21 (95% CI 1.35–3.61). **AUC VAI vs WC**: 0.62 (0.58–0.66) Vs 0.55 (0.51–0.6) p < 0.001
6.	Janghorbani, M[19]	2016	Iran (1720)	Prospective Cohort (5–10 years)	ORadj 3rd quintile 1.5 (95% CI 0.9–2.49); 4th quintile 1.86 (95% CI 1.18–3.08); dan 5th quintile 1,99 (95% CI 1.22–3.25). **AUC VAI vs WC** (0.581 Vs 0.61)
7.	Zhang, M[22]	2016	Cina (4078)	Prospective Cohort (4 years)	Male: Hradj 2nd tertile 1.18 (95% CI 1.118–2.958; p = 0.016), 3rd tertile HRadj 2.854 (95% CI 1.815–4.487) Female: 3rd tertile 3.351 (95% CI 1.586–7.955; p = 0.002). **AUC VAI vs WC** (Male: 0.641 Vs 0.624; Female 0.7171 Vs 0.724)

AUC: Area Under The Curve, VAI: Visceral Adipose Index, WC: Waist Circumference, ORadj: Odd Ratio adjusted, HRadj: Hazard Ratio adjusted, SD: Standard Deviation.

waist circumference in predicting T2DM [18,19,22].

The critical review and risk of bias assessments (Table 2) were conducted by using Newcastle Ottawa Scale (NOS). All studies were considered high quality with a score of 7 or more. Four studies that received score of 7, in which performed by Janghorbani et al. [19], Liu et al. [14], Wang et al. [18], and Zhang et al. [22] recruited subjects from the health centres, not community-based. While one study by Zhang et al. [22] had a relatively short observation period of 4 years. Furthermore, two studies by Liu et al. [14] and Wang et al. [18] did not state the source of funding.

Table 2
Newcastle Ottawa Scale from selected studies.

Studies	Selection	Comparability	Outcome	Total
Liu et al. [14]	***	**	***	8
Gu et al. [17]	****	**	***	9
Wang et al. [18]	****	**	**	8
Du [15]	****	**	***	9
Chen et al. [16]	****	**	***	9
Janghorbani [19]	***	**	**	7
Zhang [22]	***	**	**	7

4. Discussion

Our study found that in Asian population, VAI was an independent predictor for T2DM. The prediction value of VAI for T2DM in Asian population was relatively higher compared to the reported value in Caucasian population by Kavaric et al. [OR adjusted 1.292 (95% CI 1.133–1.474)] [20]. This finding was consistent with the previous studies which reported that Asian population had a relatively higher VAT accumulation compared to the Caucasian population [9,23,24].

It is important to note that there was no fix cut off point of VAI in all included studies. Each study had a different cut off points of VAI that might be caused by the differences in body composition for each population. To this extent, the use of VAI in different population needs to be validated to determine the best cut off point for each population. Alternatively, each population might need to develop their own formula for VAI which is ideally generated from each population local data.

In our study, we also compared the predictive value of VAI to waist circumference, a simple anthropometric VAT measurement. Two studies reported that VAI had a better predictive value compared to waist circumference, study by Liu et al. [14] showed AUC male population 0.617 vs. 0.601 and in female population 0.762 vs. 0.663 and study by Chen et al. [16] AUC 0.62 (0.58–0.66) vs. 0.55 (0.51–0.6) $p < 0.001$. which was in line with the finding from a study in Saudi Arabia (AUC 0.715 vs. 0.65) [25], while three studies by Janghorbani et al. [19], Zhang et al. [22] and Gu et al. [17] reported no significant difference. The different findings might be caused by the variability of study population, length of observation period, sampling techniques and also proportion of sample drop-outs. The study by Janghorbani et al. [19] had quite a high drop-out proportion (51%), while the study by Zhang et al. [22] had a relatively short observation period of 4 years. Hence, it might affect the results of the analysis.

Our study had some limitations, of which the most notable was the existing population of the included studies were localized only in one district or area. Therefore, they might not represent the whole country population. Furthermore, all of these studies were performed in 3 countries (China, Iran, and Saudi Arabia), thus not all major Asian ethnicities were represented.

In summary, VAI is a practical formula to estimate the accumulation of visceral fat that can be used as a predictor of T2DM in Asian population with better prediction values compared to the Caucasian population. However, the question on whether these findings can also be applicable to other major Asian ethnicities, such as the Malay ethnicity, needs further studies.

Consent for publication

All authors consent to publish this study. The authors guarantee that any data of this study has not been published anywhere else as a whole or in part. All authors have declared to approve the publication of this study and any person named as co-author is aware and agreed of the publication and the order authors naming.

Availability of data and material

The authors confirm that the data supporting the results of this study are available within the article and or the supplementary material.

Competing interest

The authors declare that they have no competing interest.

Author contribution

Idea and study design: DLT, RN, PS; Data collection and analysis: RN, DLT; Article draft writing: RN; Draft revision: DLT, PS; Writing supervision: DLT, PS.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2019.01.056.

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