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Relationship between serum osteocalcin/undercarboxylated osteocalcin and type 2 diabetes: A systematic review/meta-analysis study protocol

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Relationship between serum osteocalcin/undercarboxylated osteocalcin and type 2 diabetes: a systematic review/meta-analysis study protocol

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ABSTRACT

Introduction The global burden of type 2 diabetes (T2DM) is steadily increasing. Experimental studies have demonstrated that a novel hormone secreted by bone cells, osteocalcin (OC), can stimulate beta-cell proliferation and improve insulin sensitivity in mice. Observational studies in humans have investigated the relationship between OC and metabolic parameters, and T2DM. Importantly, few studies have reported on the undercarboxylated form of OC (ucOC), which is the putative active form of OC suggested to affect glucose metabolism.

Objectives We will conduct a systematic review and meta-analysis to: (1) compare the levels of serum OC and ucOC between T2DM and normal glucose-tolerant controls (NGC); (2) investigate the risk ratios between serum OC and ucOC, and T2DM; (3) determine the correlation coefficient between OC and ucOC and fasting insulin levels, homeostatic model assessment-insulin resistance, haemoglobin A1c and fasting glucose levels and (4) explore potential sources of between-study heterogeneity. The secondary objective is to compare the serum OC and ucOC between pre-diabetes (PD) and NGC and between T2DM and PD.

Methods and analysis This study will report items in line with the guidelines outlined in preferred reporting items for systematic reviews and meta-analysis of observational studies in epidemiology. We will include observational studies (cohort, case-control and cross-sectional studies) and intervention studies with baseline data. Three databases (MEDLINE, EMBASE and SCOPUS) will be searched from inception until July 2018 without language restrictions. Two reviewers will independently screen the titles and abstracts and conduct a full-text assessment to identify eligible studies. Discrepancies will be resolved by consensus with a third reviewer. The risk of bias assessment will be conducted by two reviewers independently based on the Newcastle-Ottawa Scale. Potential sources of between-study heterogeneity will be tested using meta-regression/subgroup analyses. Contour-enhanced funnel plots and Egger’s test will be used to identify potential publication bias.

Ethics and dissemination Formal ethical approval is not required. We will disseminate the results to a peer-reviewed publication and conference presentation.

PROSPERO registration number CRD42017073127.

INTRODUCTION

The disease burden attributed to diabetes is high. Currently, around 425 million people have diabetes, with 90% of these having type 2 diabetes (T2DM).1 It is estimated that by 2045, this figure will have increased to 629 million people.1 Patients with T2DM present increased levels of glucose than people with normal glycaemic metabolism. Also, those patients have increased risks of other complications, such as heart attacks, strokes, diabetic retinopathy and renal disease.2 Correspondingly, several organs become the targets to treat, prevent or predict diabetes, such as pancreatic beta cells, muscle, liver, adipose tissue, kidney, the gastrointestinal tract or the brain.3 Interestingly, a recent study has identified a new potential tissue to treat diabetes: the skeleton and bone. Increasing numbers of osteokines secreted by
Osteocalcin (OC) is an osteoblast-secreted protein that plays a role in the communication between the skeleton and glucose homeostasis. There are two forms of OC: undercarboxylated osteocalcin (ucOC) and carboxylated osteocalcin (cOC). cOC contributes to the extracellular bone matrix, while ucOC is likely the active form of OC in the circulation. Both cOC and ucOC are present in the circulation, and their combined amount is referred to as total osteocalcin (TOC). TOC is considered a marker of bone turnover.

A potential endocrine function of OC was first suggested in 2007. Lee et al and Ferron et al reported OC-mediated glucose homeostasis via stimulating beta-cell proliferation and adiponectin secretion in mice. The endocrine actions of OC involve increasing insulin synthesis and secretion by beta-cells and improved insulin sensitivity by promoting adiponectin secretion in adipocytes. The high-fat diet experimental study revealed that bone could become insulin resistant by inhibiting the activation of OC. However, reported associations between OC and T2DM in humans have yielded conflicting results. Previous reviews explored different sources of heterogeneity; the high between-study heterogeneity. Third, we will identify studies comparing ucOC and glucose homeostasis in T2DM. Lastly, by systematic review and meta-analysis aims to:

1. Explain previous conflicting findings.
2. Identify more prospective studies, thereby increasing the statistical power. Second, we will search for studies reporting the association between ucOC and glucose homeostasis in T2DM. Third, we will identify studies comparing the OC concentrations between PD and normal glucose controls and comparing OC levels between T2DM and PD may contribute to the investigation between OC and glucose homeostasis in patients with diabetes.

Another unsolved issue in the previously published meta-analyses is the high between-study heterogeneity. Previous reviews explored different sources of heterogeneity with modest success. Starup-Linde et al conducted subgroup analysis according to sex, age and menopausal status in women. Liu C et al attempted to explain the heterogeneity by sex and OC assay methods. Kunutsor et al conducted subgroup analyses according to study design and degree of confounders of risk estimates. Hygum et al performed a meta-regression analysis to investigate the extent to which heterogeneity was explained by haemoglobin A1c (HbA1c) levels.

Therefore, the present systematic review/meta-analysis will use a more comprehensive search strategy to identify more prospective studies, thereby increasing the statistical power. Second, we will search for studies reporting the association between ucOC and glucose metabolism. Third, we will identify studies comparing the OC concentrations between PD and normal glucose controls, and between T2DM and PD. Lastly, by systematically exploring potential sources of heterogeneity we may explain previous conflicting findings.

OBJECTIVES
The present systematic review and meta-analysis aims to:

1. Compare the levels of serum OC and ucOC between
2. Explain the heterogeneity by sex and OC assay methods.
Eligibility criteria for studies included in the review
Inclusion and exclusion criteria

Participants
Participants should be adult humans (older than 18 years old), with T2DM at the baseline or developed T2DM afterwards; not have any conditions that can affect bone metabolism or with medications that affect bone metabolism; and could be on anti-diabetic treatment.

Exclude:
1. Children or adolescents (younger than 18 years), and pregnant or lactating women due to altered bone turnover marker levels.
2. Patients with a disease that either affects bone metabolism or glucose metabolism.
3. Patients with type 1 diabetes and/or gestational diabetes as they are pathophysiologically different from patients with type 2 diabetes (T2DM).
4. Patients with Cushing’s disease or Cushing’s syndrome as they have disordered metabolism.
5. Patients with hormonal disorders. For instance, growth-hormone deficiency or excess.
6. Patients with hyperparathyroidism or hypoparathyroidism or other diseases that affect thyroid function.
due to increased osteocalcin (OC) levels and changes in metabolism.

7. Patients with liver dysfunction (alanine transaminase level >3 times upper limit of normal).

8. Patients with impaired kidney function as described below:
   - Chronic renal disease patients with glomerular filtration rate below 30 mL/min·1.73 m² at stage four or five, or
   - Chronic renal disease patients with serum creatinine level over 2.07 mg/dL, or renal osteodystrophy, or kidney transplant as 21%–50% of kidney transplant recipients may develop secondary hyperparathyroidism after kidney transplantation or when treated with dialysis or hemodialysis.

9. Patients with Paget’s disease as they have disordered bone metabolism.

10. Patients with osteomalacia as it is a severe bone disease and affects bone metabolism.

11. Patients with cancer or tumours. For example, bone metastases could affect bone turnover marker levels.

12. Patients with HIV infection.

13. Patients with sepsis as they have disordered immune response caused by infections.

14. Patients on medications that affect bone metabolism:
   - Antiresorptive or anabolic therapy for osteoporosis and selective oestrogen receptor modulators (such as bisphosphonates, alendronate, etidronate, raloxifene, denosumab and teriparatide).
   - Oestrogen replacement therapy.
   - Glucocorticoids and thiazide diuretics.

15. Patients treated with surgery that directly affects hormone or thyroid function (ie, thyroidectomy, oophorectomy and hysterectomy).

Note:
1. We include intervention studies that reported baseline data of OC and T2DM. Accordingly, we will eliminate observational studies with more than 20% of the cohort taking above non-eligible therapy.

2. We included T2DM with diabetic medications, but they will be assessed using subgroup analysis by medication status. Anti-diabetic medications that affect OC/ucOC levels include insulin therapy, glucagon-like peptide-1 (GLP-1) receptor agonists, and thiazolidinediones.

**Study types**
Observational studies are eligible for inclusion: cohort studies (both prospective and retrospective cohort studies), case-control studies and cross-sectional studies, reporting eligible exposure(s) and outcome(s).

We will exclude reviews, commentaries, short surveys, case reports, and letters.

Interventional studies (including randomised controlled trials) will be used if they provide eligible cross-sectional data at the baseline before intervention.

**Exposure(s)**
OC levels are identified from ELISA, electrochemiluminescence immunoassay, immunoradiometric assay, radioimmunoassay and hydroxyapatite binding assay. The standard unit for OC is ng/mL; thus, other presented groups for OC (eg, nmol/L) will be converted to ng/mL.

**Measures of OC**
- Total serum OC levels (ng/mL).
- ucOC levels (ng/mL).
- OC categorised as low (reference) and high groups. Tertile, quartile or quantile are the common categories used for classifying different levels of TOC or ucOC.

**Outcome(s)**

**Measures of T2DM**
- Diabetes status categorised as T2DM disease or normal controls (reference).
- As some studies may categorise diabetes states as insulin-dependent diabetes mellitus and non-insulin dependent diabetes mellitus (NIDDM), NIDDM will be used and presented as T2DM.
- Exclude type 1 diabetes and gestational diabetes as they are pathophysiologically different compared with T2DM.

**Secondary outcome(s)**
- Impaired glucose tolerance/impaired fasting glucose: that is the pre-diabetic state with a higher risk of developing T2DM.
- HbA1c levels categorised as T2DM, PD and healthy controls (reference) by HbA1c rates over 6.5%, between 5.7% and 6.5%, and below 5.7%, respectively.
- Fasting plasma glucose levels categorised as diabetes, PD and healthy controls (reference) by FPG levels over 126 mg/dL, between 100 and 126 mg/dL, and below 100 mg/dL, respectively.

**Study design**

**Search strategies**
A comprehensive literature search within MEDLINE, EMBASE and SCOPUS databases will be conducted to source all possible relevant studies for the present review. There is no language restriction, and non-English articles will be translated when possible and evaluated for eligibility. There is no time restriction. We may include conference proceedings and abstracts if necessary. We will further conduct reference list searches of each available paper. If duplicate publications of the same study are retrieved, the most relevant and up to date paper with more complete data will be included. The detailed search strategy is shown in table 1.

**Process for selecting studies**
One author will set-up the search strategy and store the search results in Endnote X7. The search strategy and recorded search results will then be checked by another investigator. Two or more independent investigators will perform the abstract screening (to remove duplicate...
records of the same report and to include eligible articles, and full-text assessment (to acquire full-texts of available studies and to construct citation lists of eligible items). If a discrepancy arises, the disagreement will be discussed with investigators by email or face-to-face meetings before reaching a final decision.

**Data extraction**

Two authors will independently extract data from studies that are eligible for full-text assessment. If any discrepancy arises, a third reviewer will examine the data. All extracted data will be saved in an Excel spreadsheet.

Eligible extracted items: author and publication year, study design, study base, sample size, sex and postmenopausal status in females, age, ethnicity, country, OC assay methods, obesity measurements (body mass index or waist circumference), duration of diabetes, anti-diabetic medications status, vitamin K supplementation/anti-vitamin K drugs, vitamin D supplementation, TOC/ucOC levels in groups, any association between TOC/ucOC and HbA1c and/or FPG in T2DM, any association between TOC/ucOC and PD and/or impaired glucose tolerance/impaired fasting glucose, any association between TOC/ucOC and HbA1c and/or FPG in T2DM, any association between TOC/ucOC and T2DM, any association between TOC/ucOC and standard glucose controls, and any association between TOC/ucOC and HOMA-IR or HOMA-beta in T2DM.

**Risk of bias assessment**

The methodological quality will be assessed using the Newcastle-Ottawa Scale (NOS). Cohort and case-control studies can be assessed by three main parts in the NOS: selection, comparability and outcome/exposure. The maximum score is nine points. A higher score indicates better methodological quality of the individual study. Cross-sectional studies can be assessed using the modified NOS. The maximum score is 10 points for the modified NOS, representing the highest quality. The quality assessment template can be found in the supplementary materials (online appendix 3).

**Statistical analysis and data synthesis**

Mean differences with 95% CI will be calculated between T2DM and NGC, between PD and NGT, and between T2DM and PD. Estimates of effect size will be expressed as relative risk with 95% CI for cohort studies and OR with 95% CI for case-control and cross-sectional studies. OR is expressed as one increased SD of OC to the risk of developing T2DM. Papers reporting other forms of OR will be translated to per increased SD of OC if a logistic regression model is used. Pearson’s correlation coefficient will be calculated between TOC or ucOC and fasting insulin levels. Studies that only have medians and ranges or IQRs will be transformed to means and SD. Furthermore, log-transformed data will be converted to raw statistics before subjecting to analyses. We will assess publication bias of mean differences and risk estimates by visual inspection of the funnel plots. Egger’s test will be used to assess the publication bias when there is a large number of studies. We will evaluate heterogeneity employing the I² statistic by study ID which quantifies inconsistency across studies to assess the impact of heterogeneity on the meta-analysis. I² represents the degree of heterogeneity. I² thresholds of 0%–40%, 30%–60%, 50%–90% and 75%–100% indicate possibilities of low, moderate, substantial and considerable heterogeneity.
respectively. It is suggested to use Rstudio for conducting meta-analyses (V.1.1.419-2009-2019; RStudio). The ‘metafor’ package will be used to perform meta-regression analyses, meta-bias analyses and for assessing heterogeneities. Each p value of <0.05 indicates statistical significance.

**Meta-regression/subgroup analysis**
Meta-regression analysis and subgroup analysis will be applied to assess the sources of heterogeneity. Meta-regression will be used for continuous factors such as age, sample size and proportion of postmenopausal women. We will use subgroup analyses to identify potential sources of clinical, methodological or statistical heterogeneity for categorical variables. We will also generate mix-effect models to evaluate the influence of multiple factors on the effect size. Random-effects models will be used, and p values of <0.01 will be considered statistically significant for subgroup analyses. Pre-planned subgroup analyses to explore statistical heterogeneity will include stratification by:

- Subgroups based on study design.
- Subgroups based on age.
- Subgroups based on sex. In addition, a subset based on menopausal status will be assessed among females.
- Subgroups based on ethnicity or race.
- Subgroups based on diabetic status (normal, PD, T2DM).
- Subgroups based on anti-diabetic medication status in T2DM.
- Subgroups based on obesity measurements (body mass index/waist circumference).
- Subgroups based on OC assay methods.
- Subgroups based on fasting measures and spot measures.
- Subgroups based on vitamin K supplementation/anti-vitamin K drugs or vitamin D supplementation if data are available.

**Publication bias and confidence in cumulative evidence**
Publication bias assessment is based on graphical test (funnel plots) and Egger’s and Begg’s tests. The asymmetry of the funnel plot suggests a higher risk of publication bias and vice versa. Statistically, Egger’s and Begg’s tests will be conducted using RStudio.

We will provide assurance of the quality of our results by applying the Grading of Recommendations Assessment Development and Evaluation (GRADE) tool. We will also present an evidence profile summary using GRADEpro software (http://ims.cochrane.org/gradepro). The quality checklist includes the following items: risk of bias assessment, consistency of results, directness of evidence and precision of the results.

**DISCUSSION**
The current systematic review/meta-analysis constitutes an update and improvement to the current literature in several ways. First, we will provide more evidence compared with previous investigations in analysing the potential role/s OC plays in T2DM by increasing the number of eligible studies included in our up-to-date analysis. Second, we will investigate the sources of heterogeneity, explicitly by an increase in the number of factors such as age, sex, postmenopausal status in women, study design, ethnicity or regions, OC assays and medications on T2DM. This comprehensive analysis of heterogeneity may uncover the factor(s) responsible for the differences among already published studies. Third, we will produce a report not only on TOC levels, but also on ucOC levels. By including investigations on ucOC, we can determine the endocrine roles of both OC and ucOC in humans, if any. In addition, investigating the relationship in a subgroup of patients with PD will provide more details regarding the influence of OC (or ucOC) on glucose levels in a progressive T2DM status. The major limitation of this review is that we will only be including observational studies as there is insufficient evidence from clinical trials, which will restrict study results in specific analyses. According to the search results for clinical studies, if there are any eligible interventional studies, we will include them but only use the baseline data in which case we will regard those studies as cross-sectional studies. Despite this disadvantage, there are still a large number of studies that could be used to pool a quantitative analysis and provide evidence according to concerns with heterogeneity. Our review will contribute to public health and clinical research for further investigations regarding the gap in the current literature.

**Contributors**
All authors contributed to the study concept and design. YHL led the writing of the manuscript and is the primary designer of the protocol under the guidance of AP. TBS, JL, KB and AP conceived the conceptual ideas presented in the manuscript. YHL and XYL collected the data for screening. YHL, XYL, JL, KB, TBS and AP revised the protocol critically. All authors read and approved the revised version and final supported versions.

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**Competing interests**
None declared.

**Patient consent for publication**
Not required.

**Ethics approval**
The present study will be published in a peer-reviewed journal when completed. If appropriate, we will present novelty findings at a relevant conference.

**Provenance and peer review**
Not commissioned; externally peer reviewed.

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