Obesity Facts

Obes Facts , DOI: 10.1159/000533828
Received: November 12, 2022
Accepted: August 14, 2023
Published online: August 28, 2023

A systematic review and meta-analysis of vitamin D status of patients with severe obesity in various regions worldwide

Haghighat N, Sohrabi Z, Bagheri R, Akbarzadeh M, Esmaeilnezhad Z, Ashtary-Larky D, Barati-Boldaji R, Zare M, Amini M, Hosseini SV, Wong A, Foroutan H

ISSN: 1662-4025 (Print), eISSN: 1662-4033 (Online)
https://www.karger.com/OFA
Obesity Facts

Disclaimer:
Accepted, unedited article not yet assigned to an issue. The statements, opinions and data contained in this publication are solely those of the individual authors and contributors and not of the publisher and the editor(s). The publisher and the editor(s) disclaim responsibility for any injury to persons or property resulting from any ideas, methods, instructions or products referred to the content.

Copyright:
This article is licensed under the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC) (http://www.karger.com/Services/OpenAccessLicense). Usage and distribution for commercial purposes requires written permission.

© 2023 The Author(s). Published by S. Karger AG, Basel

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

A systematic review and meta-analysis of vitamin D status of patients with severe obesity in various regions worldwide

Running title: vitamin D status of patients and severe obesity

Neda Haghighat[1], Zahra Sohrabi[2], Reza Bagheri[3], Marzieh Akbarzadeh[2], Zahra Esmaeilnezhad[2], Damoon Ashtary-Larky[1], Reza Barati-Boldaji[2], Morteza Zare[2], Masoud Amini[1], Seyed Vahid Hosseini[4], Alexei Wong[5], Hamidreza Foroutan[1]
[1]Laparoscopy Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Department of Community Nutrition, Shiraz University of Medical Sciences, Shiraz, Iran
[3] Department of Exercise Physiology, University of Isfahan, Isfahan, Iran.
[4]Colorectal Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
[5]Department of Health and Human Performance, Marymount University, Arlington, VA, United States.

Corresponding Author: Dr. Hamidreza Foroutan, Laparoscopy Research Center, Ghadir Mother and Child Hospital, Town Gulshan, Shiraz, Fars, P.O. Box: 71449-95377, Iran.
Tel: +98-71-32279701;
Fax: +9871-32279701
Email: forotanh@sums.ac.ir
Key words: Obesity, Vitamin D, Vitamin D Deficiency, Meta-Analysis

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Abstract
Introduction: Managing nutritional deficiencies is an essential component in the treatment of severe obesity. Vitamin D deficiency is often reported in investigations in severe obese cohorts. However, no prior study has summarized findings on this topic. Consequently, the aim of this systematic review and meta-analysis was to investigate the 25-hydroxyvitamin D [25(OH)D] status in individuals with severe obesity in different regions worldwide. We also evaluated levels of calcium, PTH, and magnesium as secondary outcome measures.
Methods: We searched Medline, PubMed, Scopus, the Cochrane Library, and EMBASE for relevant observational studies published in English from 2009 to October 2021. The heterogeneity index among the studies was determined using the Cochran (Q) and I^2 tests. Based on the heterogeneity results, the random-effect model was applied to estimate the prevalence of vitamin D deficiency.
Results: We identified 109 eligible observational studies. Overall, 59.44% of patients had vitamin D deficiency [25(OH)D <20 ng/ml], whereas 26.95% had vitamin D insufficiency [25(OH)D 20-30 ng/ml]. Moreover, the mean 25(OH)D levels was 18.65 ng/ml in 96 studies. The pooled mean estimate of the serum calcium, PTH and magnesium was 9.26 mg/dl (95% CI: 9.19-9.32, I^2=99.7%, p<0.001), 59.24 pg/ml (95% CI: 54.98, 63.51), I^2= 99.7%, p < 0.001), and 0.91 mg/dl (0.84, 0.98, I^2= 100.0%, p < 0.001), respectively. The results of the sub-group analysis indicated that the mean estimates of 25(OH)D was highest in North America [21.71 ng/ml (19.69, 23.74), (I^2=97.2%, p<0.001)] and lowest in Southeast Asia [14.93 ng/ml (14.54, 15.33), (I^2=0.0%, p = 0.778)].
Conclusion: The results obtained showed a significant prevalence of vitamin D deficiency among severely obese individuals in various geographical regions, whereas the highest and lowest mean estimates were reported for North America and Southeast Asia, respectively.

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Introduction:

Morbid obesity, characterized by body mass index (BMI) higher than 40 kg/m, showed an increased prevalence in the last 30 years [1]. It is associated with significant severity and mortality including enhanced morbidity from cardiovascular, cerebrovascular, hepatobiliary and colonic diseases [2-4]. It is well established that despite high-calorie intakes, micronutrient deficiencies are prevalent in severe obesity [5, 6]. Indeed, a high body mass index is correlated with nutrient deficiency [7-11]. Therefore, the management of nutrient deficiencies in severe obesity is an important component for the treatment of this condition, especially since these deficiencies could worsen after the surgeries [12].

Vitamin D deficiency is often reported in severe obese cohorts [13], and its prevalence is further increased in those that are candidates for bariatric surgery [14-19]. The causes for vitamin D deficiency in this population include a lower sun exposure due to lower outdoor physical activity [6, 20], a reduced dietary intake of vitamin D as well as an impaired liver function which decreases the synthesis of this vitamin [12]. Moreover, vitamin D uptake [21, 22] and vitamin D sequestration by the adipose tissue can be considered another important trigger of vitamin D deficiency in the severely obese cohort [23-25]. Lower vitamin D levels [12] in severe obesity are frequently concurrent to higher parathyroid hormone (PTH) concentrations which can impair calcium metabolism and lead to declines in bone health and the development of chronic diseases, including diabetes, cardiovascular disease, and hypertension [26-37]. Various degrees of vitamin D deficiency and high PTH levels in severe obese cohorts are reported in the available literature, which results from various fortification policies, seasonal and geographical differences, assay methods, and ethnicity differences [12]. For instance, some studies reported a vitamin D deficiency prevalence of 50-60 % [38, 39], while others showed more than 70 % in bariatric surgery candidates [12, 18, 40, 41]. It should be noted that previous studies reported that PTH levels link to calcium, and magnesium levels [42, 43].

Vitamin D deficiency is the most common cause of secondary hyperparathyroidism that will result in bone resorption and fracture. Moreover, vitamin D deficiency can decelerate chronic disease including metabolic syndrome, type 2 diabetes, hypertension and hyperlipidemia in patients with severe obesity [44]. Consequently, there is a lack of consensus regarding serum levels of vitamin D, PTH, calcium, and magnesium in this population. It is important to better elucidate vitamin D status in various geographical zones for better management of this deficiency before the surgeries in this high-risk group. Thus, we sought to conduct a systematic review and meta-analysis to assess vitamin D deficiency prevalence as well as serum levels of vitamin D, magnesium, calcium, and PTH in severely obese individuals in different regions worldwide.

Materials and Methods

This study was performed based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for reporting systematic reviews and meta-analyses [45]. The protocol was previously published in the PROSPERO database (http://www.crd.york.ac.uk/PROSPERO), under registration no. CRD42019139937.

Search Strategy

We searched PubMed, Scopus, EMBASE, ISI web of sciences, and Cochrane databases through October 2021 in the English language to find studies investigating the prevalence of vitamin D status in patients with severe obesity who were candidates for bariatric surgeries. The systematic literature search was based on the following strategy: controlled vocabulary (i.e., MeSH and EMTREE Terms) and specific text words. For each database search, adapted combinations of terms and words were applied. For example, in the search on the PubMed database, the following search terms were used: ("vitamin D", "25-hydroxy vitamin D", "vitamin D deficiency", 25(OH) D, "Vitamin D deficiency" OR "Deficiency, Vitamin D" OR "Deficiencies, Vitamin D" OR "Vitamin D Deficiencies") AND ("morbid obesity" OR "severe obesity" OR "Morbid Obesities" OR "Obesities, Morbid" OR "Obesity, Severe" OR "Obesities, Severe" OR "Severe Obesities" OR "Severe Obesities"). Moreover, bibliographies of all prior reviews and primary studies identified by search strategy were scanned for additional relevant publications. The authors decided which trials to include (authors 1, 2, and 3) in a blinded manner, with discrepancies resolved via discussion.

Inclusion and Exclusion Criteria

Three reviewers independently screened all abstracts and selected articles for the meta-analysis if they met all of the following criteria: prospective or retrospective studies or randomized controlled trials that reported the level of serum vitamin d, calcium, PTH, and magnesium status or prevalence of vitamin d deficiency or insufficiency in individuals with severe obesity (BMI>40 or BMI>35 with at least one comorbidity) preoperatively [46](2) written in

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

the English language, and (3) reported at least serum vitamin D or calcium or PTH or magnesium or vitamin D deficiency or insufficiency. Only data associated with severe obesity were considered for inclusion in studies that analyzed multiple interventions. The exclusion criteria were (1) the absence of information on serum vitamin D or calcium or PTH or magnesium or prevalence of vitamin d deficiency or insufficiency (2) studies with case-control design, reviews, comments, case reports, abstracts, and animal studies.

Study Selection

Three authors (N.H., Z.S., and M.A) independently conducted the study selection process in two phases. The first phase consisted of screening the articles through their titles and abstracts and eliminating studies that did not meet the eligibility criteria. The remaining articles were read in full, and those eligible were selected for review. In the absence of consensus on including a study by the three authors, a fourth author (M.A.) contributed to the final decision-making. The level of disagreement was calculated using a percentage of agreement and reliability, Cohen's Kappa [47]. Three authors (N.H., Z.S., and M.A.) analyzed the lists of references of the included articles.

Data Collection

Three authors (S.E., R.B., and M.A.) extracted the data, and an additional author (N.H.) performed the crosschecking of all information. The following details were collected from all selected studies: authors, publication year, the aim of the study, sample size, age, sex, country of origin, serum vitamin D level, serum calcium level, serum PTH level, serum Magnesium level, and their deficiencies.

Statistical Analysis

The statistical analyses were performed using Stata, version 14 (Stata Corp, College Station, TX). We calculated the mean difference (MD) with 95% confidence intervals (CI) for continuous data for each study. Cochrane Q test and I^2 were used to evaluate heterogeneity among the included studies. I^2 values greater than 50% represented moderate to high heterogeneity, and $P < 0.01$ was considered statistically significant. Because of the significant heterogeneity, the pooled weighted mean difference (WMD) and 95% confidence intervals (CI) were calculated using the random-effects model (DerSimonian and Laird) [12]. The subgroup analysis was performed to explore possible sources of observed heterogeneity among the included studies. Subgroup analysis was conducted according to the following variables: climate zone (Middle East, North America, South America, Asia, Europe) (*P* values for pooled effect sizes were considered statistically significant at the level of $P < 0.05$, *a priori*.

Results

Literature search:

In the initial search, 10491 papers were found from the selected databases. After exclusion of the duplicates, 1778 documents underwent assessment via screening of titles and abstracts. Of these, 1086 papers were determined as non-relevant, while the remaining 692 papers underwent full-text revision. Following these procedures, 119 documents were determined as eligible, and another 18 studies were added for consideration after assessment of the article's references. The evaluation of inclusion/exclusion criteria resulted in the omission of 25 records. Consequently, 109 articles were included in the meta-analysis (Figure 1).

Study characteristics:

The study design of the included studies was cross-sectional, case-control, cohorts, and interventional, which reported serum 25(OH)D, PTH, calcium, and magnesium levels in patients with severe obesity and bariatric surgery candidates. Included studies were published from 2009 to 2021, consisting of 109 papers on bariatric surgery candidates reporting their pre-operation information. The total number of individuals who underwent meta-analysis from 109 articles was 21565, which varied from 10 to 2008. The mean age of the individuals was 41.5 years varying from 30 to 51 years. Both male and female participants were included in 109 Papers, while 13 papers were reported on data related to only females (Table 1).

Meta-analysis:

Vitamin D status

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

Vitamin D deficiency and insufficiency was reported in 51 and 28 studies conducted on 12479 and 3390 individuals, respectively. The overall pooled prevalence estimates of vitamin D status were as follow; vitamin D deficiency (25(OH)D <20 ng/ml): 59.44% (95% CI: 54.16, 64.73, I^2 =100.0%, p<0.001), vitamin D insufficiency (25(OH)D 20-30 ng/ml): 26.95% (95% CI: 22.12, 31.78, I^2=100.0%, p<0.001) and vitamin D deficiency + insufficiency (25(OH)D < 30 ng/ml): 76.24% (95% CI: 66.96, 85.52, I^2=100.0%, p<0.001) (Figure 2A-C, respectively).

A mean serum level of 25(OH)D was reported in 96 studies on 18998 individuals. The pooled mean estimate of the serum 25(OH) D level was 18.65 ng/ml (95% CI: 17.85, 19.45, I^2=99.4%, p <0.001). The lowest and highest serum 25(OH)D levels were reported in Lancha (2014)'s and Damms-Machado (2012)'s reports, respectively (Figure 3A).

The mean serum levels of 25(OH)D were also analyzed in different geographical zones. Based on the results of subgroup analysis, the pooled mean estimate of serum 25(OH) D levels in different geographical zones was as follows;

Europe 18.94 ng/ml (17.86, 20.02), (I^2= 99.5%, p<0.001)

Middle East 15.29 ng/ml (13.93, 16.65), (I^2=98.3%, p<0.001)

Southeast Asia 14.93 ng/ml (14.54, 15.33), (I^2=0.0%, p = 0.778)

South America 21.12 ng/ml (16.07, 26.16), (I^2=99.1%, p<0.001)

North America 21.71 ng/ml (19.69, 23.74), (I^2=97.2%, p<0.001)

Australia 17.77 ng/ml (14.90, 20.63), (I^2=79.1%, p=0.001)

The highest and lowest mean estimates were reported for North America and Southeast Asia, respectively (Table 2).

Parathyroid hormone

Fifty-nine studies reported serum PTH levels of the 11545 individuals. The pooled mean estimate of serum PTH level was 59.24 pg/ml (95% CI: 54.98, 63.51), I^2= 99.7%, p < 0.001) (Figure 3B). In a subgroup analysis based on the geographical location, the highest and lowest pooled mean estimates were seen in South America and Southeast Asia, respectively (Table 2).

Calcium

Data on serum calcium levels of 13355 individuals were reported in 56 studies. According to the meta-analysis, the pooled mean estimate of the serum calcium level was 9.26 mg/dl (95% CI: 9.19-9.32, I^2=99.7%, p<0.001) (Figure 3C). Subgroup analysis by geographical location established that Australia (pooled mean estimate of 9.36 mg/dl (9.25, 9.47, I^2=98.2%, p<0.001)) and South America (pooled mean estimate of 9.00 mg/dl (8.53, 9.48, I^2=99.2%, p<0.001)) had highest and lowest estimates, respectively (Table 2).

Magnesium

Data on serum magnesium levels were reported in 15 studies, including 2527 individuals. The pooled mean estimate of the serum magnesium level was 0.91 (0.84, 0.98, I^2= 100.0%, p < 0.001) (Figure 3D). Subgroup analysis based on the geographical location determined that North America had the highest serum magnesium level estimate (1.44 mg/dl (0.77, 2.11) (I^2= 99.7%, p = 0.000 (Table 2)).

Sensitivity analysis:

According to the sensitivity analysis, omitting each individual study did not affect the result of the meta-analysis significantly.

Discussion:

This is the first systematic review and meta-analysis to evaluate vitamin D status and serum calcium, magnesium, and PTH in bariatric surgery candidates (severely obese people). Vitamin D status is essential for bone mineralization and muscle function, especially in patients with severe obesity at higher risk of deficiency before and after bariatric surgeries [41]. Vitamin D deficiency has been associated with increased risk of inflammatory diseases and also bone disease including rickets, osteomalacia, and osteoporosis [48]. According to the pooled estimates in the current meta-analysis, 59.44% of patients had vitamin D deficiency, and 26.95% had insufficiency. Considering the studies reporting deficiency + insufficiency, 76.24% had this condition. The pooled mean serum vitamin D was 18.65 ng/ml. Moreover, our sub-group analysis based on the geographical zones showed that the highest estimated vitamin D levels were reported in North and South America, and the lowest levels were seen in Southeast Asia and the Middle East.

In accordance with our findings, a prior study reported a 57.4% deficiency of vitamin D (<20 ng/ml) in severely obese bariatric surgery candidates [38]. However, there was a higher prevalence of vitamin D deficiency in the black (78.4%) compared to white cohort (36.5%), which seems logical due to the higher skin pigmentation of the black individuals [38]. Skin pigmentation such as melanin, absorbs the ultraviolet radiation that initiates vitamin D synthesis, and hence

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

decreases the vitamin D that is made for a given exposure compared to less pigmented skin [49]. Our results are also in line with the previous investigations reporting more than 50% of vitamin D deficiency in patients with severe obesity [12, 18, 39, 40]. In regards to serum levels of vitamin D, some studies reported higher [39], while some reported lower levels [12, 18]. Variations between studies about the exact estimates of vitamin D deficiency prevalence or vitamin D concentrations can possibly be due to the differences among studies regarding population, geographical locations, seasonal variations, race, gender, culture, religion, among others. On the other hand, the policy of different countries regarding food fortification can affect vitamin D intake and status in various regions [12]. For example, a large improvement of vitamin D status in different counties have been reported is due to fortification of dairy products with vitamin D [50-52]. Moreover, fortification of fruit juice, flour, cooking oil and rice showed positive results in improving vitamin D status [53-55]. Furthermore, different studies used various methods or labs for evaluating vitamin D status, and the results should be interpreted with caution [56].

There are many potential causes for vitamin D deficiency in severely obese individuals. One of the most important ones is related to the less sun exposure of this group due to decreased outdoor activities [6, 20]. Another reason may be lower intakes of dietary sources of vitamin D, including fortified foods, in this population. On the other hand, vitamin D deficiency can emanate from vitamin D sequestration in the adipose tissue or uptake by this tissue in obese people [23-25, 57]. Further, it is hypothesized that fatty liver in severely obese people can impair liver vitamin D synthesis [12]. Nevertheless, due to its effects on bone mineralization and muscle function and its correlation with various diseases [26-37, 58], optimizing vitamin D status in patients with severe obesity is an essential component for the treatment of this condition, especially since these vitamin D deficiency could worsen after the bariatric surgery [12].

Our sub-group analysis revealed that lowest vitamin D levels were reported in Southeast Asia and the Middle East. Contrary to our findings, it was reported that vitamin D deficiency prevalence gradually increased in South East Asia due to the excellent sun exposure of the residents in these areas in the past. However, even in Southeast Asian countries with good sun exposure, many people have limited sun exposure due to lifestyle changes. These changes include fewer outdoor activities, better access to transportation. In addition, some traditional protections (masks, gloves, etc.), especially at the hotter times of the day (ex: noon) may cause lower sun exposure [59]. On the other hand, vitamin D-rich foods are few, and they are not consumed frequently by Southeast Asian inhabitants [60]. Indeed, strong recommendations exist to improve vitamin D status in Southeast Asia through different strategies, including food fortification [59].

Regarding lower vitamin D concentration in the Middle East, it is reported that vitamin D deficiency and insufficiency can be seen frequently in the Middle East despite year-round sunny days. The main reason for such observation is pertinent to the traditional attire of the population of this geographical area [61]. The clothing style in the Middle East can deteriorate vitamin D status as their clothes are different from the western style due to Hijab and Nigab [62-64]. Moreover, in many Middle East countries, outdoor physical activity is limited due to the hot and humid climate (such as Arab countries), and this can decrease sun exposure and adversely affect vitamin D status [41, 65]. Dietary factors and cultural beliefs can also affect vitamin D status and deficiency [61]. Lower calcium intake in the Middle East can also affect vitamin D status [61], which can cause rickets or secondary hyperparathyroidism and eventually low bone mass density. Other factors affecting lower vitamin D levels in the Middle East include urban living and pollution [66]. Additionally, lower vitamin D supplementation and lower intakes of vitamin-D-rich foods such as cod liver oil and oily fish are dietary factors associated with vitamin D deficiency in the Middle Easterners. Further, some genetic factors and polymorphisms related to vitamin D metabolism and degradation could adversely affect vitamin D status [56].

According to the current meta-analysis, another region with low vitamin D levels is Australia. According to Nowson et al., the deficiency was more pronounced in dark-skinned people and veiled women. However, due to the lack of sun exposure in the winter, Australia's deficiency is more observed. Another problem that needs to be resolved in the region is making a balance between sun exposure and sunshine avoidance for skin cancer protection [67]. In a nationally representative sample of Australian adults aged ≥25 years, one in five Australian resident (19% men; 21% women) were classified as vitamin D deficient, and 43% classified as insufficient (45% men; 42% women) [68]. According to this study, independent predictors of vitamin D deficiency in Australia are being born in a country other than Australia or the main English-speaking countries, residing in southern (higher latitude) states of Australia, being assessed during winter or spring, being obese, smoking (women only), having low physical activity levels and not

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

taking vitamin D or Ca supplements. According to the serum levels of vitamin D in the present study, average levels were somehow higher in Europe. In European countries, vitamin D status is better despite the deficiencies seen in some areas [56]. Large observational data have reported that almost 40% of Europeans are vitamin D deficient, and 13% are severely deficient [69]. This may vary by age, with lower levels in childhood and the elderly [70] as vitamin D deficiency is prevalent among older adults [71], and also ethnicity in different regions, for example, European Caucasians show lower rates of vitamin D deficiency compared with nonwhite individuals [69, 70]. Nordic countries in northern Europe encounter the lowest efficiencies of vitamin D due to the higher consumption of cod liver oil, supplements [72], and vitamin D-fortified foods [50]. However, poor vitamin D status was observed in the non-western immigrants in Europe [73-78].

We observed the highest vitamin D levels were observed in severe obese cohorts in the South and North American regions. This observation is in agreement with the results of a previous systematic review about vitamin D deficiency in various age groups and genders [79]. According to their findings, the highest mean vitamin D status was generally observed in North America. Extensive food fortifications can justify higher vitamin D levels in North America with vitamin D in the United States (such as cereals, milk, and juice) [80]. Higher intake of vitamin D-fortified foods by obese individuals may be the main cause of higher vitamin D levels in severe obese cohorts.

In the current study, evaluating pooled estimated serum levels of PTH in the included studies showed higher levels of PTH in the severely obese patients. However, the lowest average level was seen in the Southeast Asian. The highest average level was reported in those from South America which was higher than the normal range. Lower dietary intakes of calcium with decreased serum calcium levels can justify the higher levels of PTH in South American cohorts [81, 82], which can be detrimental for bone health.

It was previously reported that PTH levels are increased in severely obese people and are highly correlated with body mass index [83]. Vitamin D deficiency is the major cause of higher PTH levels in this population [84]. Other than an increase in PTH before bariatric surgeries, an elevation could possibly happen in PTH levels following the surgeries. It may be related to the correlations between high PTH and metabolic syndrome, non-alcoholic steatohepatitis, and lower bone mineral density [85]. Consequently, optimizing serum levels of PTH by correcting serum calcium and vitamin D is crucial in severely obese bariatric surgery candidates.

Our outcomes showed that the pooled estimate calcium levels were in the normal range. However, the lowest and highest levels were reported in South America and Australia. Literature in various populations reported lower dietary calcium intake and higher hip fractures in South America [86, 87]. In contrast, higher calcium intake has been described in Australia [88], which are in line with the serum levels of calcium reported for these regions in the present meta-analysis. The higher levels of serum calcium concentrations together with normal PTH levels in Australian severely obese individuals should be accompanied with optimal vitamin D levels to ensure bone health. However, our outcomes showed Australia is an area with low serum levels of vitamin D. Since there are a high number of bariatric surgeries in Australia [89], optimizing serum levels of vitamin D in severely obese bariatric surgery candidates seem essential.

Regarding serum magnesium levels, we established that pooled estimated magnesium level was in the normal range in severely obese bariatric surgery candidates. The higher levels were reported in North America, possibly due to adequate dietary intake, and are important for bone health. According to previous findings, obesity is not related to hypomagnesemia, and only dietary magnesium intake is related to serum magnesium levels in obese populations [90]. Most of obese individuals have high intakes of this essential nutrient from their diets [90].

The present meta-analytic work has some limitations that need to be acknowledged. For instance, the studies were only categorized according to the geographical zones for sub-group analysis as other variables were not completely (such as season of data collection). Moreover, the measurement methods of vitamin D and other values, cut-off points, limit values according to countries and regions were not the same. Furthermore, the effects of some health conditions on blood values were not considered in this study. Additionally, only few numbers of studies reported serum levels of PTH, calcium, and magnesium. Consequently, our results for these parameters should be interpreted with caution. Furthermore, we evaluated bariatric surgery candidates and our results should not generalize to those not qualifying for surgery. On the other hand, numerous studies were included in the evaluation of vitamin D, which can be considered the main strength of this meta-analysis.

Conclusion:

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

To sum up, this systematic review and meta-analysis pooled the results of vitamin D status and serum levels of PTH, calcium, and magnesium in severely obese bariatric surgery candidates. Vitamin D deficiency was observed in more than 50 percent of this population. More than 70 percent had deficiency+ insufficiency. The highest serum levels of vitamin D were reported in the South and North America, possibly due to the effect of vast fortification, and the lowest was seen in South-East Asia and the Middle East, which may be related to cultural and dietary factors. Pooled estimated serum levels of calcium and magnesium were in the normal range, and the lowest calcium levels were observed in South America. On the contrary, higher pooled estimated levels of PTH were also reported in the severely obese people and South Americans had the greatest concentrations. Due to the high prevalence of vitamin D deficiency and the risk of hyperparathyroidism before and after bariatric surgeries, optimizing vitamin D levels through better fortification and supplementation policies, especially in the high-risk populations (such as South East Asia and the Middle East) is recommended for ensuring bone health and preventing some chronic diseases. Strategies for better sun exposure are recommended for all countries. On the other hand, appropriate dietary calcium and magnesium intake and early assessment of PTH levels are recommended for this population.

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

Statement of Ethics

An ethics statement is not applicable because this study is based exclusively on published literature.

Registration and protocol

The protocol was previously published in the PROSPERO database (http://www.crd.york.ac.uk/PROSPERO), under registration no. CRD42019139937.

Funding

This study is supported by Shiraz university of medical sciences (Grant number: 26351)

Competing interests

The authors have no conflicts of interest to declare

Author contributions

Neda Haghighat and Hamidreza Foroutan contributed to conceptualization, investigation, supervision, validation, visualization, medical oversight, and preparing the original draft and final manuscript. Zahra Sohrabi, Reza Barati-Boldaji, Zahra Esmaeilnezhad and Marzieh Akbarzadeh contributed to conceptualization, data extraction, visualization, and writing the final manuscript. Morteza Zare contributed to formal analysis, methodology, software, validation. Neda Haghighat, Reza Bagheri and Damoon Ashtary-Larky contributed to investigation, conceptualization, visualization and preparing the original draft. Seyed Vahid Hosseini, Alexei Wong and Masoud Amini contributed to conceptualization, supervision, validation, project administration, and critical revision of the draft and final manuscript. All the authors approved the final manuscript.

Data Availability Statement

All data generated or analyzed during this study are included in this manuscript. Further enquiries can be directed to the corresponding author.

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

References:

1. Ricci, M.A., et al., *Facing morbid obesity: how to approach it.* 2016. **67**(4): p. 391-397.
2. Cello, J.P., S.J.J.C. Rogers, and t. gastroenterology, *Morbid Obesity—The New Pandemic: Medical and Surgical Management, and Implications for the Practicing Gastroenterologist.* 2013. **4**(6): p. e35.
3. Haghighat, N., et al., *Long-term effect of bariatric surgery on body composition in patients with morbid obesity: A systematic review and meta-analysis.* Clinical Nutrition, 2021. **40**(4): p. 1755-1766.
4. Haghighat, N., et al., *The effect of 12 weeks of euenergetic high-protein diet in regulating appetite and body composition of women with normal-weight obesity: a randomised controlled trial.* British journal of nutrition, 2020. **124**(10): p. 1044-1051.
5. Popkin, B.M., C. Corvalan, and L.M. Grummer-Strawn, *Dynamics of the double burden of malnutrition and the changing nutrition reality.* The Lancet, 2020. **395**(10217): p. 65-74.
6. Frame-Peterson, L.A., et al., *Nutrient deficiencies are common prior to bariatric surgery.* Nutrition in Clinical Practice, 2017. **32**(4): p. 463-469.
7. Ernst, B., et al., *Evidence for the necessity to systematically assess micronutrient status prior to bariatric surgery.* Obesity surgery, 2009. **19**(1): p. 66-73.
8. de Luis, D.A., et al., *Micronutrient status in morbidly obese women before bariatric surgery.* Surgery for obesity and related diseases, 2013. **9**(2): p. 323-327.
9. Lefebvre, P., et al., *Nutrient deficiencies in patients with obesity considering bariatric surgery: a cross-sectional study.* Surgery for obesity and related diseases, 2014. **10**(3): p. 540-546.
10. Peterson, L.A., et al., *Malnutrition in bariatric surgery candidates: multiple micronutrient deficiencies prior to surgery.* Obesity surgery, 2016. **26**(4): p. 833-838.
11. Lee, P.C., et al., *Nutritional deficiencies in severe obesity: a multiethnic Asian cohort.* Obesity surgery, 2019. **29**(1): p. 166-171.
12. Al-Mutawa, A., et al., *Nutritional status of bariatric surgery candidates.* Nutrients, 2018. **10**(1): p. 67.
13. Goldner, W.S., et al., *Prevalence of vitamin D insufficiency and deficiency in morbidly obese patients: a comparison with non-obese controls.* 2008. **18**(2): p. 145-150.
14. Damms-Machado, A., et al., *Pre-and postoperative nutritional deficiencies in obese patients undergoing laparoscopic sleeve gastrectomy.* Obesity surgery, 2012. **22**(6): p. 881-889.
15. Ben-Porat, T., et al., *Nutritional deficiencies after sleeve gastrectomy: can they be predicted preoperatively?* Surgery for Obesity and Related Diseases, 2015. **11**(5): p. 1029-1036.
16. Pellitero, S., et al., *Evaluation of vitamin and trace element requirements after sleeve gastrectomy at long term.* Obesity surgery, 2017. **27**(7): p. 1674-1682.
17. Ben-Porat, T., et al., *Nutritional deficiencies in patients with severe obesity before bariatric surgery: what should be the focus during the preoperative assessment?* Journal of the Academy of Nutrition and Dietetics, 2020. **120**(5): p. 874-884.
18. Pellegrini, M., et al., *Pre-operative micronutrient deficiencies in patients with severe obesity candidates for bariatric surgery.* Journal of Endocrinological Investigation, 2020: p. 1-11.
19. Ewang-Emukowhate, M., et al., *Vitamin K and other markers of micronutrient status in morbidly obese patients before bariatric surgery.* International journal of clinical practice, 2015. **69**(6): p. 638-642.
20. Stein, J., et al., *The nutritional and pharmacological consequences of obesity surgery.* Alimentary pharmacology & therapeutics, 2014. **40**(6): p. 582-609.
21. Vranić, L., I. Mikolašević, and S. Milić, *Vitamin D deficiency: consequence or cause of obesity?* Medicina, 2019. **55**(9): p. 541.
22. Paschou, S.A., et al., *The impact of obesity on the association between vitamin D deficiency and cardiovascular disease.* Nutrients, 2019. **11**(10): p. 2458.
23. Vanlint, S., *Vitamin D and obesity.* Nutrients, 2013. **5**(3): p. 949-956.
24. Tsiaras, W.G. and M.A. Weinstock, *Factors influencing vitamin D status.* Acta dermato-venereologica, 2011. **91**(2): p. 115-124.
25. Holick, M.F., *Vitamin D deficiency.* New England journal of medicine, 2007. **357**(3): p. 266-281.

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

26. Bacci, V. and G. Silecchia, *Vitamin D status and supplementation in morbid obesity before and after bariatric surgery.* Expert review of gastroenterology & hepatology, 2010. **4**(6): p. 781-794.
27. Zaghloul, S., et al., *Evidence for nutrition transition in Kuwait: over-consumption of macronutrients and obesity.* Public health nutrition, 2013. **16**(4): p. 596-607.
28. Ducloux, R., et al., *Vitamin D deficiency before bariatric surgery: should supplement intake be routinely prescribed?* Obesity surgery, 2011. **21**(5): p. 556-560.
29. Gudzune, K.A., et al., *Screening and diagnosis of micronutrient deficiencies before and after bariatric surgery.* Obesity surgery, 2013. **23**(10): p. 1581-1589.
30. Grace, P.D.C., R. Vincent, and S.J. Aylwin, *High prevalence of vitamin D insufficiency in a United Kingdom urban morbidly obese population: implications for testing and treatment.* Surgery for obesity and related diseases, 2014. **10**(2): p. 355-360.
31. Bischoff-Ferrari, H.A., et al., *Estimation of optimal serum concentrations of 25-hydroxyvitamin D for multiple health outcomes.* The American journal of clinical nutrition, 2006. **84**(1): p. 18-28.
32. Gannage-Yared, M.-H., et al., *Prevalence and predictors of vitamin D inadequacy amongst Lebanese osteoporotic women.* British Journal of Nutrition, 2008. **101**(4): p. 487-491.
33. Liu, E., et al., *Plasma 25-hydroxyvitamin D is associated with markers of the insulin resistant phenotype in nondiabetic adults.* The Journal of nutrition, 2009. **139**(2): p. 329-334.
34. Judd, S.E., et al., *Optimal vitamin D status attenuates the age-associated increase in systolic blood pressure in white Americans: results from the third National Health and Nutrition Examination Survey.* The American journal of clinical nutrition, 2008. **87**(1): p. 136-141.
35. Kim, D.H., et al., *Prevalence of hypovitaminosis D in cardiovascular diseases (from the National Health and Nutrition Examination Survey 2001 to 2004).* The American journal of cardiology, 2008. **102**(11): p. 1540-1544.
36. Alshahrani, F.M., et al., *Vitamin D: Light side and best time of sunshine in Riyadh, Saudi Arabia.* Dermato-endocrinology, 2013. **5**(1): p. 177-180.
37. Cannell, J., et al., *Diagnosis and treatment of vitamin D deficiency.* Expert opinion on pharmacotherapy, 2008. **9**(1): p. 107-118.
38. Gemmel, K., et al., *Vitamin D deficiency in preoperative bariatric surgery patients.* Surgery for Obesity and Related Diseases, 2009. **5**(1): p. 54-59.
39. Vivan, M.A., et al., *Prevalence of vitamin D depletion, and associated factors, among patients undergoing bariatric surgery in southern Brazil.* Obesity surgery, 2019. **29**(10): p. 3179-3187.
40. Tan, B.C., et al., *Preoperative Nutritional Deficiencies in Bariatric Surgery Candidates in Korea.* Obesity Surgery, 2021. **31**(6): p. 2660-2668.
41. Aridi, H.D., et al., *Prevalence of vitamin D deficiency in adults presenting for bariatric surgery in Lebanon.* Surgery for Obesity and Related Diseases, 2016. **12**(2): p. 405-411.
42. Brent, G., et al., *Relationship between the concentration and rate of change of calcium and serum intact parathyroid hormone levels in normal humans.* 1988. **67**(5): p. 944-950.
43. Navarro, J.F., et al., *Relationship between serum magnesium and parathyroid hormone levels in hemodialysis patients.* 1999. **34**(1): p. 43-48.
44. Liu, C., et al., *Changes in bone metabolism in morbidly obese patients after bariatric surgery: a meta-analysis.* Obesity surgery, 2016. **26**: p. 91-97.
45. Moher, D., et al., *Prisma Group.(2009).* Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. **6**(6): p. e1000097.
46. Sturm, R., *Increases in morbid obesity in the USA: 2000–2005.* Public health, 2007. **121**(7): p. 492-496.
47. Sim, J. and C.C. Wright, *The kappa statistic in reliability studies: use, interpretation, and sample size requirements.* Phys Ther, 2005. **85**(3): p. 257-68.
48. Rajabi, S., et al., *Vitamin D status in patients with morbid obesity following bariatric surgery in shiraz, iran: a retrospective observational study.* Bariatric Surgical Practice and Patient Care, 2022. **17**(2): p. 121-126.
49. Webb, A.R., et al., *Colour counts: sunlight and skin type as drivers of vitamin D deficiency at UK latitudes.* 2018. **10**(4): p. 457.

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

50. Jääskeläinen, T., et al., *The positive impact of general vitamin D food fortification policy on vitamin D status in a representative adult Finnish population: evidence from an 11-y follow-up based on standardized 25-hydroxyvitamin D data.* 2017. **105**(6): p. 1512-1520.
51. Brandão-Lima, P.N., et al., *Vitamin D food fortification and nutritional status in children: A systematic review of randomized controlled trials.* 2019. **11**(11): p. 2766.
52. Kiely, M., K. Cashman, and O.C.J.N. bulletin, *The ODIN project: Development of food-based approaches for prevention of vitamin D deficiency throughout life.* 2015. **40**(3): p. 235-246.
53. Nikooyeh, B., et al., *Vitamin D-fortified cooking oil is an effective way to improve vitamin D status: an institutional efficacy trial.* 2020. **59**(6): p. 2547-2555.
54. Laleye, L.C., et al., *A study on vitamin D and vitamin A in milk and edible oils available in the United Arab Emirates.* 2009. **60**(sup5): p. 1-9.
55. Jan, Y., et al., *Vitamin D fortification of foods in India: present and past scenario.* 2019. **193**: p. 105417.
56. Lips, P., et al., *Current vitamin D status in European and Middle East countries and strategies to prevent vitamin D deficiency: a position statement of the European Calcified Tissue Society.* European journal of endocrinology, 2019. **180**(4): p. P23-P54.
57. Karamizadeh, M., et al., *Developing a Model for Prediction of Serum 25-Hydroxyvitamin D Level: The Use of Linear Regression and Machine Learning Methods.* Journal of the American Nutrition Association, 2022. **41**(2): p. 191-200.
58. Ducloux, R., et al., *High vitamin D deficiency rate in metabolic inpatients: is bariatric surgery planning found guilty?* Obesity surgery, 2014. **24**(11): p. 1947-1953.
59. Yang, Z., et al., *A review of vitamin D fortification: implications for nutrition programming in Southeast Asia.* 2013. **34**(2_suppl1): p. S81-S89.
60. Whiting, S.J. and M.S.J.T.J.o.N. Calvo, *Overview of the proceedings from experimental biology 2005 symposium: optimizing vitamin D intake for populations with special needs: barriers to effective food fortification and supplementation.* 2006. **136**(4): p. 1114-1116.
61. Green, R.J., et al., *Vitamin D deficiency and insufficiency in Africa and the Middle East, despite year-round sunny days.* SAMJ: South African Medical Journal, 2015. **105**(7): p. 603-605.
62. Atli, T., et al., *The prevalence of vitamin D deficiency and effects of ultraviolet light on vitamin D levels in elderly Turkish population.* Archives of gerontology and geriatrics, 2005. **40**(1): p. 53-60.
63. Alagöl, F., et al., *Sunlight exposure and vitamin D deficiency in Turkish women.* Journal of endocrinological investigation, 2000. **23**(3): p. 173-177.
64. Mishal, A., *Effects of different dress styles on vitamin D levels in healthy young Jordanian women.* Osteoporosis international, 2001. **12**(11): p. 931-935.
65. Van den Heuvel, E., et al., *Cross-sectional study on different characteristics of physical activity as determinants of vitamin D status; inadequate in half of the population.* European journal of clinical nutrition, 2013. **67**(4): p. 360-365.
66. Barrea, L., et al., *Low serum vitamin D-status, air pollution and obesity: A dangerous liaison.* 2017. **18**(2): p. 207-214.
67. Nowson, C.A. and C. Margerison, *Vitamin D intake and vitamin D status of Australians.* Medical journal of Australia, 2002. **177**(3): p. 149-152.
68. Malacova, E., et al., *Prevalence and predictors of vitamin D deficiency in a nationally representative sample of adults participating in the 2011–2013 Australian Health Survey.* 2019. **121**(8): p. 894-904.
69. Cashman, K.D., et al., *Vitamin D deficiency in Europe: pandemic?* 2016. **103**(4): p. 1033-1044.
70. Cashman, K.D.J.C.t.i., *Vitamin D deficiency: defining, prevalence, causes, and strategies of addressing.* 2020. **106**(1): p. 14-29.
71. Nasimi, N., et al., *A novel fortified dairy product and sarcopenia measures in sarcopenic older adults: a double-blind randomized controlled trial.* Journal of the American Medical Directors Association, 2021. **22**(4): p. 809-815.
72. Steingrimsdottir, L., et al., *Relationship between serum parathyroid hormone levels, vitamin D sufficiency, and calcium intake.* Jama, 2005. **294**(18): p. 2336-2341.
73. Andersen, R., et al., *Pakistani immigrant children and adults in Denmark have severely low vitamin D status.* European Journal of Clinical Nutrition, 2008. **62**(5): p. 625-634.

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

74. Van Der Meer, I.M., et al., *Fatty fish and supplements are the greatest modifiable contributors to the serum 25-hydroxyvitamin D concentration in a multiethnic population.* Clinical endocrinology, 2008. **68**(3): p. 466-472.
75. van der Meer, I.M., et al., *High prevalence of vitamin D deficiency in pregnant non-Western women in The Hague, Netherlands.* The American journal of clinical nutrition, 2006. **84**(2): p. 350-353.
76. Meyer, H.E., et al., *Vitamin D deficiency and secondary hyperparathyroidism and the association with bone mineral density in persons with Pakistani and Norwegian background living in Oslo, Norway: The Oslo Health Study.* Bone, 2004. **35**(2): p. 412-417.
77. Islam, M.Z., et al., *Prevalence of vitamin D deficiency and secondary hyperparathyroidism during winter in pre-menopausal Bangladeshi and Somali immigrant and ethnic Finnish women: associations with forearm bone mineral density.* British journal of nutrition, 2012. **107**(2): p. 277-283.
78. Van der Meer, I.M., et al., *Prevalence of vitamin D deficiency among Turkish, Moroccan, Indian and sub-Sahara African populations in Europe and their countries of origin: an overview.* Osteoporosis international, 2011. **22**(4): p. 1009-1021.
79. Hilger, J., et al., *A systematic review of vitamin D status in populations worldwide.* British journal of nutrition, 2014. **111**(1): p. 23-45.
80. Prentice, A., *Vitamin D deficiency: a global perspective.* Nutrition reviews, 2008. **66**(suppl_2): p. S153-S164.
81. Paik, H.Y., *Dietary reference intakes for Koreans (KDRIs).* Asia Pacific journal of clinical nutrition, 2008. **17**.
82. Cooper, C., G. Campion, and L. Melton, 3rd, *Hip fractures in the elderly: a world-wide projection.* Osteoporosis international, 1992. **2**(6): p. 285-289.
83. Hamoui, N., G. Anthone, and P.F. Crookes, *Calcium metabolism in the morbidly obese.* Obesity Surgery, 2004. **14**(1): p. 9-12.
84. El-Kadre, L.J., et al., *Calcium metabolism in pre-and postmenopausal morbidly obese women at baseline and after laparoscopic Roux-en-Y gastric bypass.* Obesity surgery, 2004. **14**(8): p. 1062-1066.
85. Ghoghaei, M., et al., *Parathyroid hormone levels may predict nonalcoholic steatohepatitis in morbidly obese patients.* Hepatitis monthly, 2015. **15**(7).
86. Balk, E., et al., *Global dietary calcium intake among adults: a systematic review.* 2017. **28**(12): p. 3315-3324.
87. Cormick, G. and J.M.J.N. Belizán, *Calcium intake and health.* 2019. **11**(7): p. 1606.
88. Balk, E., et al., *Global dietary calcium intake among adults: a systematic review.* Osteoporosis International, 2017. **28**(12): p. 3315-3324.
89. Smith, F.J., et al., *Incidence of bariatric surgery and postoperative outcomes: a population-based analysis in Western Australia.* Medical journal of Australia, 2008. **189**(4): p. 198-202.
90. Guerrero-Romero, F., et al., *Obesity and hypomagnesemia.* 2016. **34**: p. 29-33.
91. Alejo Ramos, M., et al., *Secondary hyperparathyroidism in patients with biliopancreatic diversion after 10 years of follow-up, and relationship with vitamin D and serum calcium.* Obesity Surgery, 2019. **29**: p. 999-1006.
92. Al-Mutawa, A., et al., *Evaluation of nutritional status post laparoscopic sleeve gastrectomy—5-year outcomes.* Obesity surgery, 2018. **28**: p. 1473-1483.
93. Arias, P.M., et al., *Micronutrient deficiencies after Roux-en-Y gastric bypass: long-term results.* Obesity surgery, 2020. **30**: p. 169-173.
94. Asghari, G., et al., *Prevalence of micronutrient deficiencies prior to bariatric surgery: Tehran Obesity Treatment Study (TOTS).* Obesity surgery, 2018. **28**: p. 2465-2472.
95. Bandstein, M., et al., *The role of FTO and vitamin D for the weight loss effect of Roux-en-Y gastric bypass surgery in obese patients.* Obesity Surgery, 2015. **25**: p. 2071-2077.
96. Beckman, L.M., et al., *Serum 25 (OH) vitamin D concentration changes after Roux-en-Y gastric bypass surgery.* Obesity, 2013. **21**(12): p. E599-E606.
97. Ben-Porat, T., et al., *Nutritional deficiencies four years after laparoscopic sleeve gastrectomy—are supplements required for a lifetime?* Surgery for Obesity and Related Diseases, 2017. **13**(7): p. 1138-1144.
98. Bredella, M.A., et al., *Effects of Roux-en-Y gastric bypass and sleeve gastrectomy on bone mineral density and marrow adipose tissue.* Bone, 2017. **95**: p. 85-90.
99. Caron, M., et al., *Long-term nutritional impact of sleeve gastrectomy.* Surgery for Obesity and Related Diseases, 2017. **13**(10): p. 1664-1673.

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

100. Carrasco, F., et al., *Changes in bone mineral density after sleeve gastrectomy or gastric bypass: relationships with variations in vitamin D, ghrelin, and adiponectin levels.* Obesity surgery, 2014. **24**: p. 877-884.
101. Carrasco, F., et al., *Calcium absorption may be affected after either sleeve gastrectomy or Roux-en-Y gastric bypass in premenopausal women: a 2-y prospective study.* The American Journal of Clinical Nutrition, 2018. **108**(1): p. 24-32.
102. Casella, C., et al., *Predictive factors of secondary normocalcemic hyperparathyroidism after Roux-en-Y gastric bypass.* International Journal of Endocrinology, 2018. **2018**.
103. Chereau, N., et al., *Hypocalcemia after thyroidectomy in patients with a history of bariatric surgery.* Surgery for Obesity and Related Diseases, 2017. **13**(3): p. 484-490.
104. Cloutier, A., et al., *Long alimentary limb duodenal switch (LADS): a short-term prospective randomized trial.* Surgery for Obesity and Related Diseases, 2018. **14**(1): p. 30-37.
105. Coupaye, M., et al., *Comparison of nutritional status during the first year after sleeve gastrectomy and Roux-en-Y gastric bypass.* Obesity surgery, 2014. **24**: p. 276-283.
106. Rubio, M.A., et al., *Fat-soluble vitamin deficiencies after bariatric surgery could be misleading if they are not appropriately adjusted.* Nutrición Hospitalaria, 2014. **30**(1): p. 118-123.
107. Dagan, S.S., et al., *Nutritional status prior to laparoscopic sleeve gastrectomy surgery.* Obesity surgery, 2016. **26**: p. 2119-2126.
108. Dogan, K., et al., *Optimization of vitamin suppletion after Roux-en-Y gastric bypass surgery can lower postoperative deficiencies: a randomized controlled trial.* Medicine, 2014. **93**(25).
109. Ducloux, R., et al., *High vitamin D deficiency rate in metabolic inpatients: is bariatric surgery planning found guilty?* Obesity surgery, 2014. **24**: p. 1947-1953.
110. Elhag, W., et al., *Evolution of 29 anthropometric, nutritional, and cardiometabolic parameters among morbidly obese adolescents 2 years post sleeve gastrectomy.* Obesity Surgery, 2018. **28**: p. 474-482.
111. Elias, E., et al., *Bone mineral density and expression of vitamin D receptor-dependent calcium uptake mechanisms in the proximal small intestine after bariatric surgery.* Journal of British Surgery, 2014. **101**(12): p. 1566-1575.
112. Flores, L., et al., *Prospective study of individualized or high fixed doses of vitamin D supplementation after bariatric surgery.* Obesity surgery, 2015. **25**: p. 470-476.
113. Ghiassi, S., et al., *Conversion of standard Roux-en-Y gastric bypass to distal bypass for weight loss failure and metabolic syndrome: 3-year follow-up and evolution of technique to reduce nutritional complications.* Surgery for Obesity and Related Diseases, 2018. **14**(5): p. 554-561.
114. Gillon, S., et al., *Micronutrient status in morbidly obese patients prior to laparoscopic sleeve gastrectomy and micronutrient changes 5 years post-surgery.* Obesity surgery, 2017. **27**: p. 606-612.
115. Guan, B., et al., *Nutritional deficiencies in Chinese patients undergoing gastric bypass and sleeve gastrectomy: prevalence and predictors.* Obesity surgery, 2018. **28**: p. 2727-2736.
116. Guglielmi, V., et al., *Parathyroid hormone in surgery-induced weight loss: no glucometabolic effects but potential adaptive response to skeletal loading.* Endocrine, 2018. **59**: p. 288-295.
117. Smelt, H.J., S. Pouwels, and J.F. Smulders, *The influence of different cholecalciferol supplementation regimes on 25 (OH) cholecalciferol, calcium and parathyroid hormone after bariatric surgery.* Medicina, 2019. **55**(6): p. 252.
118. Henfridsson, P., et al., *Micronutrient intake and biochemistry in adolescents adherent or nonadherent to supplements 5 years after Roux-en-Y gastric bypass surgery.* Surgery for Obesity and Related Diseases, 2019. **15**(9): p. 1494-1502.
119. Hultin, H., K. Stevens, and M. Sundbom, *Cholecalciferol injections are effective in hypovitaminosis D after duodenal switch: a randomized controlled study.* Obesity Surgery, 2018. **28**: p. 3007-3011.
120. Johnson, L.M., et al., *Analysis of vitamin levels and deficiencies in bariatric surgery patients: a single-institutional analysis.* Surgery for Obesity and Related Diseases, 2019. **15**(7): p. 1146-1152.
121. Karefylakis, C., et al., *Vitamin D status 10 years after primary gastric bypass: gravely high prevalence of hypovitaminosis D and raised PTH levels.* Obesity surgery, 2014. **24**: p. 343-348.
122. Kim, M.K., et al., *Effects of bariatric surgery on metabolic and nutritional parameters in severely obese K orean patients with type 2 diabetes: A prospective 2-year follow up.* Journal of Diabetes Investigation, 2014. **5**(2): p. 221-227.

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

123. Lanzarini, E., et al., *High-dose vitamin D supplementation is necessary after bariatric surgery: a prospective 2-year follow-up study.* Obesity surgery, 2015. **25**: p. 1633-1638.
124. Lee, P.C., et al., *Nutritional deficiencies in severe obesity: a multiethnic Asian cohort.* Obesity Surgery, 2019. **29**: p. 166-171.
125. Luger, M., et al., *Effects of omega-loop gastric bypass on vitamin D and bone metabolism in morbidly obese bariatric patients.* Obesity surgery, 2015. **25**: p. 1056-1062.
126. Luger, M., et al., *Vitamin D 3 loading is superior to conventional supplementation after weight loss surgery in vitamin D-deficient morbidly obese patients: a double-blind randomized placebo-controlled trial.* Obesity surgery, 2017. **27**: p. 1196-1207.
127. Luger, M., et al., *Changes in bone mineral density following weight loss induced by one-anastomosis gastric bypass in patients with vitamin D supplementation.* Obesity Surgery, 2018. **28**: p. 3454-3465.
128. Malek, M., et al., *Dietary intakes and biochemical parameters of morbidly obese patients prior to bariatric surgery.* Obesity surgery, 2019. **29**: p. 1816-1822.
129. Menegati, G.C., et al., *Nutritional status, body composition, and bone health in women after bariatric surgery at a University Hospital in Rio de Janeiro.* Obesity surgery, 2016. **26**: p. 1517-1524.
130. Mihmanli, M., et al., *Effects of laparoscopic sleeve gastrectomy on parathyroid hormone, vitamin D, calcium, phosphorus, and albumin levels.* Obesity Surgery, 2017. **27**: p. 3149-3155.
131. Moore, C.E. and V. Sherman, *Vitamin D supplementation efficacy: sleeve gastrectomy versus gastric bypass surgery.* Obesity surgery, 2014. **24**: p. 2055-2060.
132. KosisochiObinwanne, K.M., et al., *Effects of laparoscopic Roux-en-Y gastric bypass on bone mineral density and markers of bone turnover.* Surgery for Obesity and Related Diseases, 2014. **10**(6): p. 1056-1062.
133. Obispo Entrenas, A., et al., *Relationship between vitamin D deficiency and the components of metabolic syndrome in patients with morbid obesity, before and 1 year after laparoscopic Roux-en-Y gastric bypass or sleeve gastrectomy.* Obesity surgery, 2017. **27**: p. 1222-1228.
134. Ong, M.W., C.H. Tan, and A.K.S. Cheng, *Prevalence and determinants of vitamin D deficiency among the overweight and obese Singaporeans seeking weight management including bariatric surgery: a relationship with bone health.* Obesity Surgery, 2018. **28**: p. 2305-2312.
135. Pellitero, S., et al., *Evaluation of vitamin and trace element requirements after sleeve gastrectomy at long term.* Obesity surgery, 2017. **27**: p. 1674-1682.
136. Perin, J., et al., *A randomized trial of a novel chewable multivitamin and mineral supplement following Roux-en-Y gastric bypass.* Obesity Surgery, 2018. **28**: p. 2406-2420.
137. Marengo, A.P., et al., *Is trabecular bone score valuable in bone microstructure assessment after gastric bypass in women with morbid obesity?* Nutrients, 2017. **9**(12): p. 1314.
138. Quraishi, S.A., et al., *Association between preoperative 25-hydroxyvitamin D level and hospital-acquired infections following Roux-en-Y gastric bypass surgery.* JAMA surgery, 2014. **149**(2): p. 112-118.
139. Raoof, M., et al., *Effect of gastric bypass on bone mineral density, parathyroid hormone and vitamin D: 5 years follow-up.* Obesity surgery, 2016. **26**: p. 1141-1145.
140. Rodríguez, R.D., et al., *Vitamin D levels and bone turnover markers are not related to non-alcoholic fatty liver disease in severely obese patients.* Nutricion hospitalaria, 2014. **30**(6): p. 1256-1262.
141. Ruiz-Tovar, J., et al., *Short-and mid-term changes in bone mineral density after laparoscopic sleeve gastrectomy.* Obesity surgery, 2013. **23**: p. 861-866.
142. van Rutte, P.v., et al., *Nutrient deficiencies before and after sleeve gastrectomy.* Obesity surgery, 2014. **24**: p. 1639-1646.
143. Sánchez, A., et al., *Micronutrient deficiencies in morbidly obese women prior to bariatric surgery.* Obesity surgery, 2016. **26**: p. 361-368.
144. Schaaf, C. and J. Gugenheim, *Impact of preoperative serum vitamin D level on postoperative complications and excess weight loss after gastric bypass.* Obesity surgery, 2017. **27**: p. 1982-1985.
145. Schafer, A.L., et al., *Intestinal calcium absorption decreases dramatically after gastric bypass surgery despite optimization of vitamin D status.* Journal of Bone and Mineral Research, 2015. **30**(8): p. 1377-1385.
146. Schijns, W., et al., *Do specialized bariatric multivitamins lower deficiencies after RYGB?* Surgery for Obesity and Related Diseases, 2018. **14**(7): p. 1005-1012.

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

147. Schijns, W., et al., *Loose and frequent stools and PTH levels are positively correlated post–gastric bypass surgery due to less efficient intestinal calcium absorption.* Surgery for Obesity and Related Diseases, 2016. **12**(8): p. 1548-1553.
148. Shahraki, M.S., et al., *Severe obesity and vitamin D deficiency treatment options before bariatric surgery: a randomized clinical trial.* Surgery for Obesity and Related Diseases, 2019. **15**(9): p. 1604-1611.
149. Sundbom, M., B. Berne, and H. Hultin, *Short-term UVB treatment or intramuscular cholecalciferol to prevent hypovitaminosis D after gastric bypass—a randomized clinical trial.* Obesity surgery, 2016. **26**: p. 2198-2203.
150. Svanevik, M., et al., *Bone turnover markers after standard and distal Roux-en-Y gastric bypass: results from a randomized controlled trial.* Obesity Surgery, 2019. **29**: p. 2886-2895.
151. Dos Santos, M.T.A., et al., *Is there association between vitamin D concentrations and body mass index variation in women submitted to Y-roux surgery?* Journal of obesity, 2018. **2018**.
152. Vilarrasa, N., et al., *Effect of bariatric surgery on bone mineral density: comparison of gastric bypass and sleeve gastrectomy.* Obesity surgery, 2013. **23**: p. 2086-2091.
153. Vinolas, H., et al., *Oral hydration, food intake, and nutritional status before and after bariatric surgery.* Obesity surgery, 2019. **29**: p. 2896-2903.
154. Vivan, M.A., et al., *Prevalence of vitamin D depletion, and associated factors, among patients undergoing bariatric surgery in Southern Brazil.* Obesity Surgery, 2019. **29**: p. 3179-3187.
155. Vix, M., et al., *Impact of Roux-en-Y gastric bypass versus sleeve gastrectomy on vitamin D metabolism: short-term results from a prospective randomized clinical trial.* Surgical endoscopy, 2014. **28**: p. 821-826.
156. Wei, J.-H., et al., *High incidence of secondary hyperparathyroidism in bariatric patients: comparing different procedures.* Obesity surgery, 2018. **28**: p. 798-804.
157. Worm, D., et al., *Changes in hematology and calcium metabolism after gastric bypass surgery—a 2-year follow-up study.* Obesity surgery, 2015. **25**: p. 1647-1652.
158. Yu, E.W., et al., *Two-year changes in bone density after Roux-en-Y gastric bypass surgery.* The Journal of Clinical Endocrinology & Metabolism, 2015. **100**(4): p. 1452-1459.
159. Zarshenas, N., et al., *Investigating nutritional deficiencies in a group of patients 3 years post laparoscopic sleeve gastrectomy.* Obesity surgery, 2016. **26**: p. 2936-2943.
160. Zubiaga Toro, L., et al., *Fórmula CUN-BAE y factores bioquímicos como marcadores predictivos de obesidad y enfermedad cardiovascular en pacientes pre y post gastrectomía vertical.* Nutrición Hospitalaria, 2014. **30**(2): p. 281-286.
161. Lancha, A., et al., *Comparative effects of gastric bypass and sleeve gastrectomy on plasma osteopontin concentrations in humans.* Surgical endoscopy, 2014. **28**: p. 2412-2420.
162. Wolf, E., et al., *Oral high-dose vitamin D dissolved in oil raised serum 25-hydroxy-vitamin D to physiological levels in obese patients after sleeve gastrectomy—a double-blind, randomized, and placebo-controlled trial.* Obesity surgery, 2016. **26**: p. 1821-1829.
163. Peterson, L.A., et al., *Malnutrition in bariatric surgery candidates: multiple micronutrient deficiencies prior to surgery.* Obesity surgery, 2016. **26**: p. 833-838.
164. Topaloğlu, Ö., et al., *The Frequency of Vitamin D Deficiency in Obese Patients on Bariatric Surgery Wait List: Is there any Association with Co-existence of Prediabetes or Diabetes?* 2019.
165. Blom-Høgestøl, I.K., et al., *Bone metabolism, bone mineral density and low-energy fractures 10 years after Roux-en-Y gastric bypass.* Bone, 2019. **127**: p. 436-445.
166. Jonas, M.I., et al., *Vitamin D receptor gene expression in adipose tissue of obese individuals is regulated by miRNA and correlates with the pro-inflammatory cytokine level.* International Journal of Molecular Sciences, 2019. **20**(21): p. 5272.
167. Marques Loureiro, L., et al., *Does the metabolically healthy obese phenotype protect adults with class III obesity from biochemical alterations related to bone metabolism?* Nutrients, 2019. **11**(9): p. 2125.
168. Ministrini, S., et al., *Determinants of high parathyroid hormone levels in patients with severe obesity and their relationship with the cardiometabolic risk factors, before and after a laparoscopic sleeve gastrectomy intervention.* Obesity Surgery, 2020. **30**: p. 2225-2232.
169. Damms-Machado, A., et al., *Pre-and postoperative nutritional deficiencies in obese patients undergoing laparoscopic sleeve gastrectomy.* Obesity surgery, 2012. **22**: p. 881-889.

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

170. Belfiore, A., et al., *Short-term changes in body composition and response to micronutrient supplementation after laparoscopic sleeve gastrectomy.* Obesity surgery, 2015. **25**: p. 2344-2351.
171. Capoccia, D., et al., *Laparoscopic gastric sleeve and micronutrients supplementation: our experience.* Journal of obesity, 2012. **2012**.
172. Toh, S.Y., N. Zarshenas, and J. Jorgensen, *Prevalence of nutrient deficiencies in bariatric patients.* Nutrition, 2009. **25**(11-12): p. 1150-1156.
173. Chan, L.-N., et al., *Optimization of vitamin D status after Roux-en-Y gastric bypass surgery in obese patients living in northern climate.* Obesity surgery, 2015. **25**: p. 2321-2327.
174. Salazar, D.A., et al., *Variable thresholds of vitamin D plasma levels to suppress PTH: the effect of weight and bariatric surgery.* Obesity surgery, 2020. **30**: p. 1551-1559.
175. Fox, W., et al., *Long-term micronutrient surveillance after gastric bypass surgery in an integrated healthcare system.* Surgery for Obesity and Related Diseases, 2019. **15**(3): p. 389-395.
176. Silveira, E.A., et al., *Serum and dietary vitamin D in individuals with class II and III obesity: prevalence and association with metabolic syndrome.* Nutrients, 2021. **13**(7): p. 2138.
177. Pinto, S.L., L.L. Juvanhol, and J. Bressan, *Weight loss after RYGB is associated with an increase in serum vitamin D in a population with low prevalence of hypovitaminosis D at low latitude.* Obesity Surgery, 2020. **30**: p. 4187-4191.
178. Wang, C., et al., *Bone metabolism in Chinese patients after laparoscopic Roux-en-Y gastric bypass.* Translational Cancer Research, 2020. **9**(4): p. 2534.
179. Altawil, E., et al., *Secondary hyperparathyroidism in obese patients post sleeve gastrectomy.* Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 2021: p. 4059-4066.
180. Pellegrini, M., et al., *Pre-operative micronutrient deficiencies in patients with severe obesity candidates for bariatric surgery.* Journal of Endocrinological Investigation, 2021. **44**: p. 1413-1423.
181. Ballesteros-Pomar, M.D., et al., *Biliopancreatic diversion for severe obesity: long-term effectiveness and nutritional complications.* Obesity surgery, 2016. **26**: p. 38-44.
182. van der Beek, E.S., et al., *Nutritional deficiencies in gastric bypass patients; incidence, time of occurrence and implications for post-operative surveillance.* Obesity surgery, 2015. **25**: p. 818-823.
183. Duran, İ.D., et al., *Differences in calcium metabolism and thyroid physiology after sleeve gastrectomy and Roux-En-Y gastric bypass.* Obesity Surgery, 2019. **29**: p. 705-712.
184. Pilone, V., et al., *Clinical factors correlated with vitamin D deficiency in patients with obesity scheduled for bariatric surgery: A single center experience.* International Journal for Vitamin and Nutrition Research, 2020.
185. Kessler, Y., et al., *Nutritional status following one anastomosis gastric bypass.* Clinical Nutrition, 2020. **39**(2): p. 599-605.
186. Almesri, N., et al., *Gender-dependent association of vitamin D deficiency with obesity and hypercholesterolemia (LDLC) in adults.* Endocrine, Metabolic & Immune Disorders-Drug Targets (Formerly Current Drug Targets-Immune, Endocrine & Metabolic Disorders), 2020. **20**(3): p. 425-436.
187. Lin, E., et al., *Contribution of adipose tissue to plasma 25-hydroxyvitamin D concentrations during weight loss following gastric bypass surgery.* Obesity, 2011. **19**(3): p. 588-594.
188. Moizé, V., et al., *Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-En-Y gastric bypass in a mediterranean population.* Journal of the Academy of Nutrition and Dietetics, 2013. **113**(3): p. 400-410.
189. Nath, A., et al., *Bowel symptoms are associated with hypovitaminosis D in individuals with medically complicated obesity.* Nutrition Research, 2019. **63**: p. 70-75.
190. Wang, C., et al., *Prevalence of electrolyte and nutritional deficiencies in Chinese bariatric surgery candidates.* Surgery for Obesity and Related Diseases, 2016. **12**(3): p. 629-634.
191. Peterson, L.A., et al., *Treatment for vitamin D deficiency prior to bariatric surgery: a prospective cohort study.* Obesity surgery, 2016. **26**: p. 1146-1149.

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

Figures legends

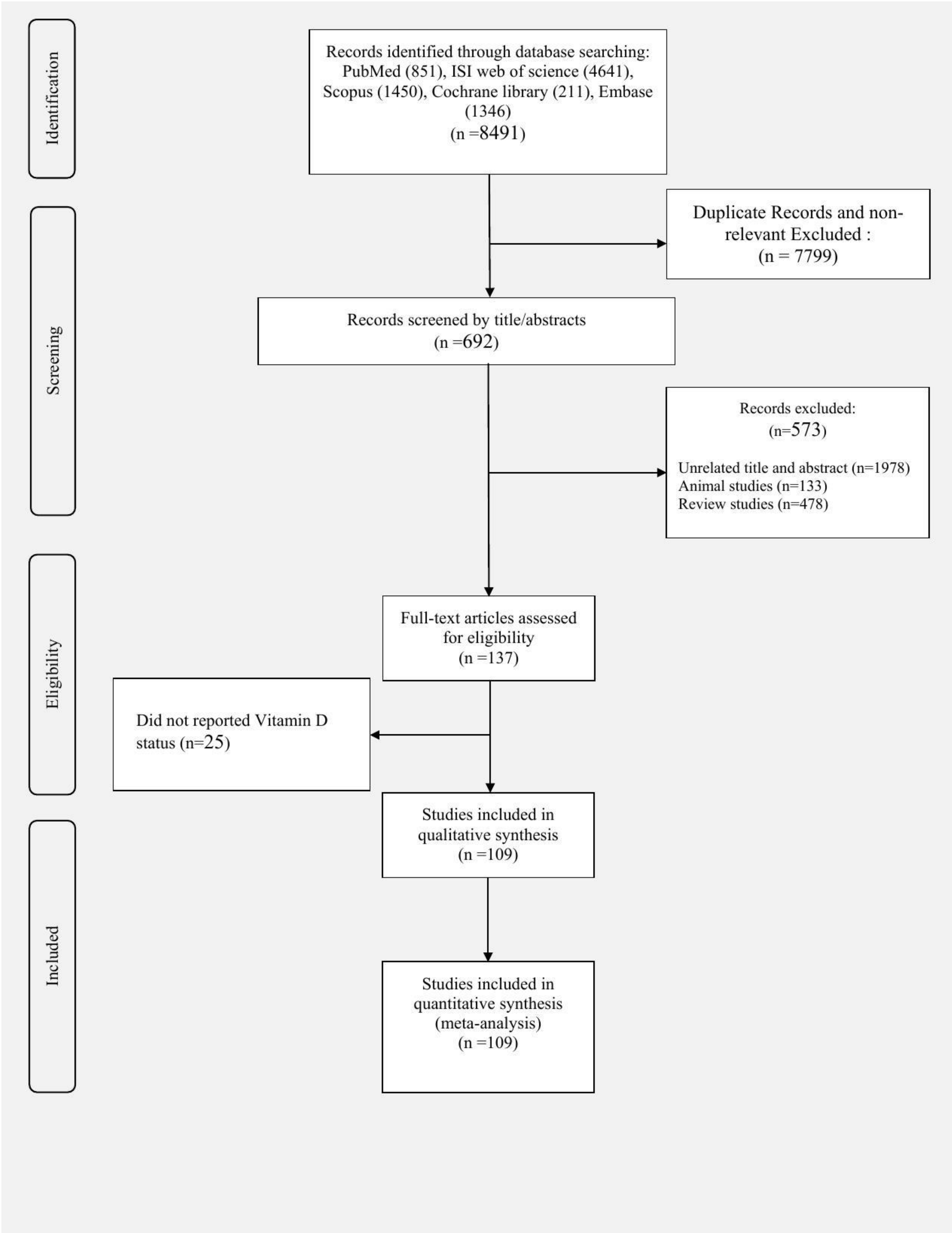
Figure 1. Flowchart of study selection for inclusion trials in the systematic review.

Figure 2. Forest plots of the pooled prevalence estimate of vitamin D status in morbidly obese patients or bariatric surgery candidates, 25(OH)D < 30 ng/ml (A), 25(OH)D < 20 ng/ml (B), 25(OH)D 20-30 ng/ml (C)

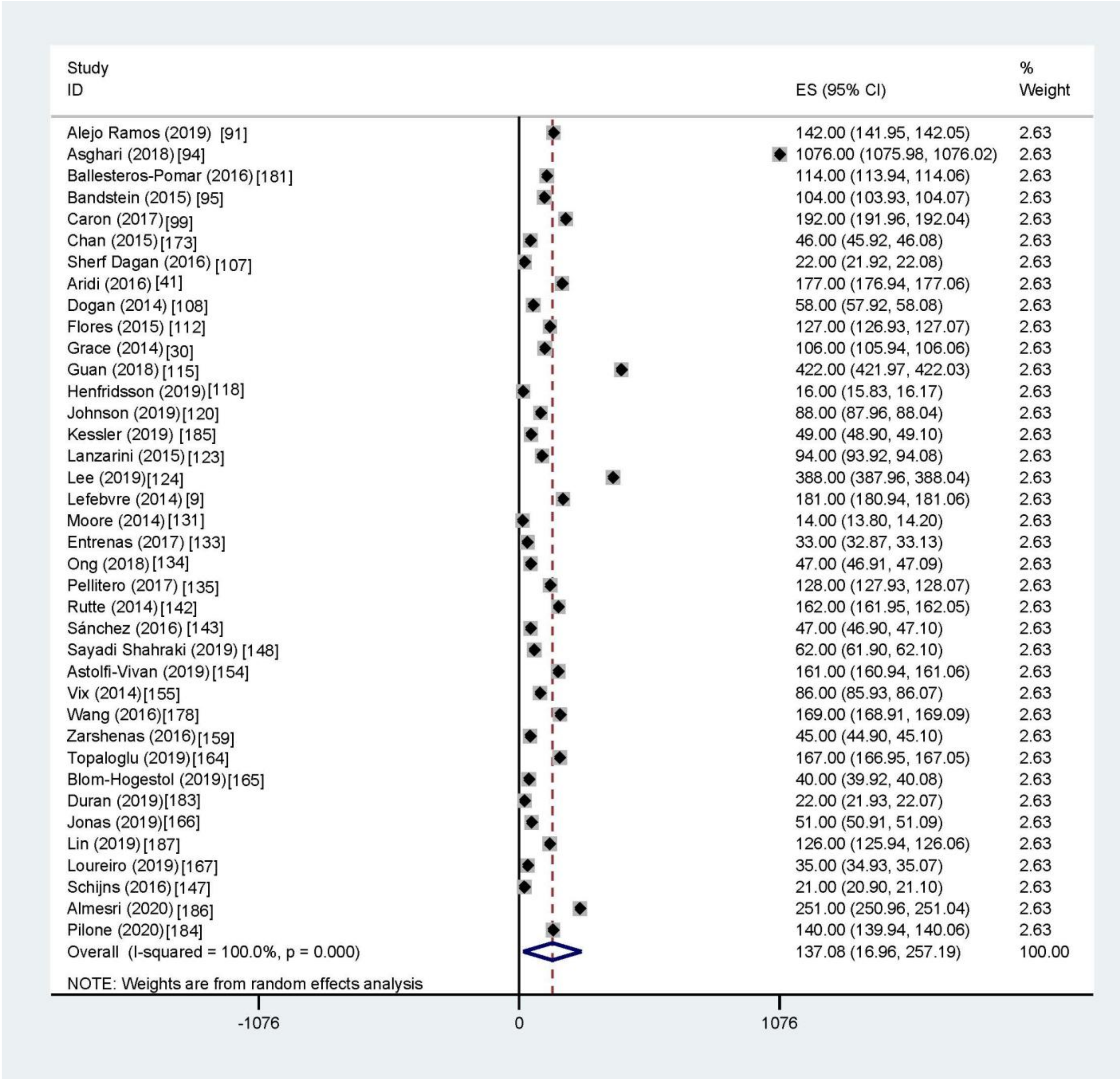
Figure 3. Forest plots of the pooled mean estimates of serum 25(OH)D (A), PTH (B), calcium (C) and magnesium (D) in morbidly obese patients or bariatric surgery candidates. (in subgroup analysis, 1: Europe, 2: Africa, 3: North America, 4: South America, 5: Australia, 6: Middle East, 7: South East Asia)

Accepted Manuscript

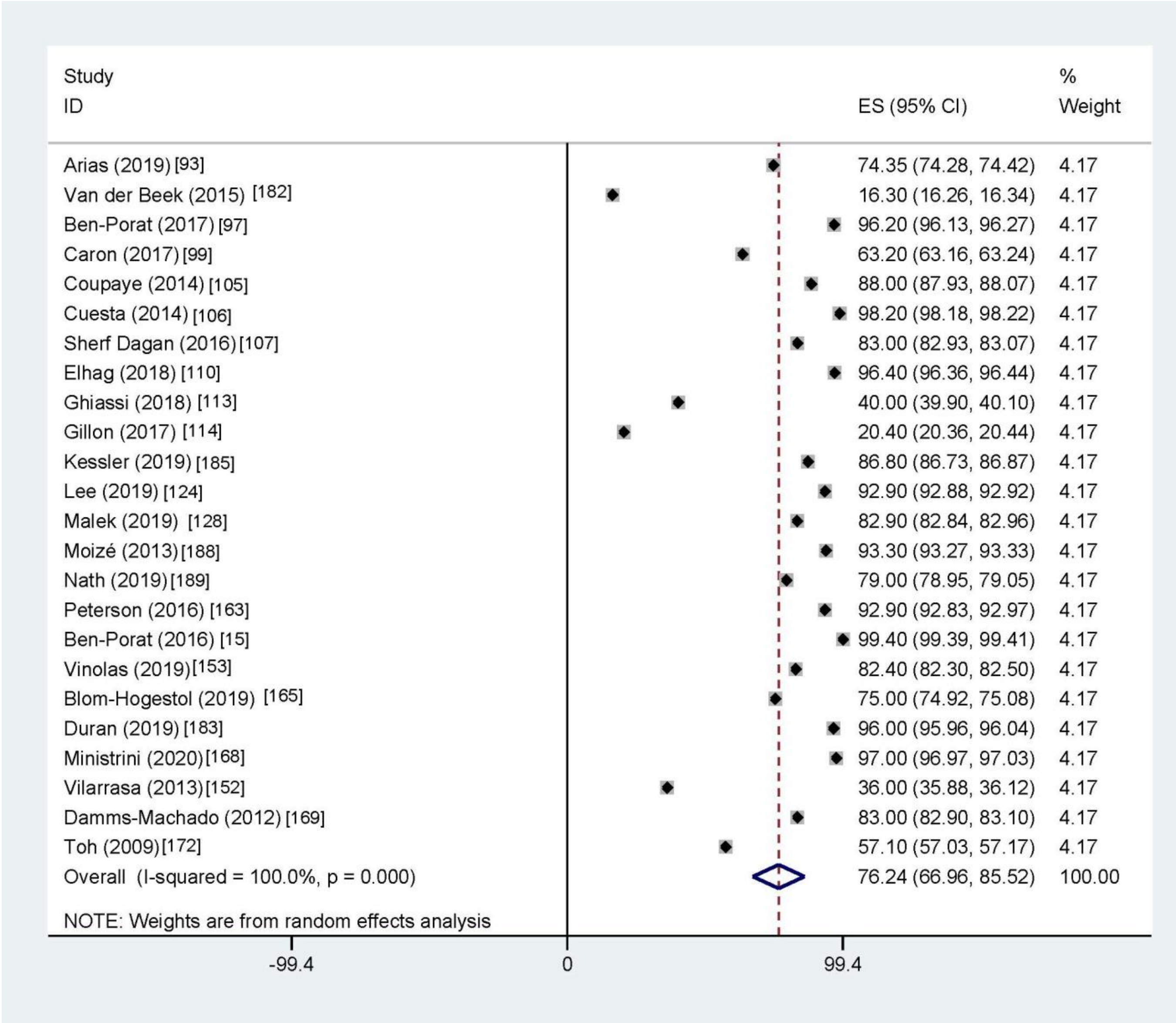
Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023



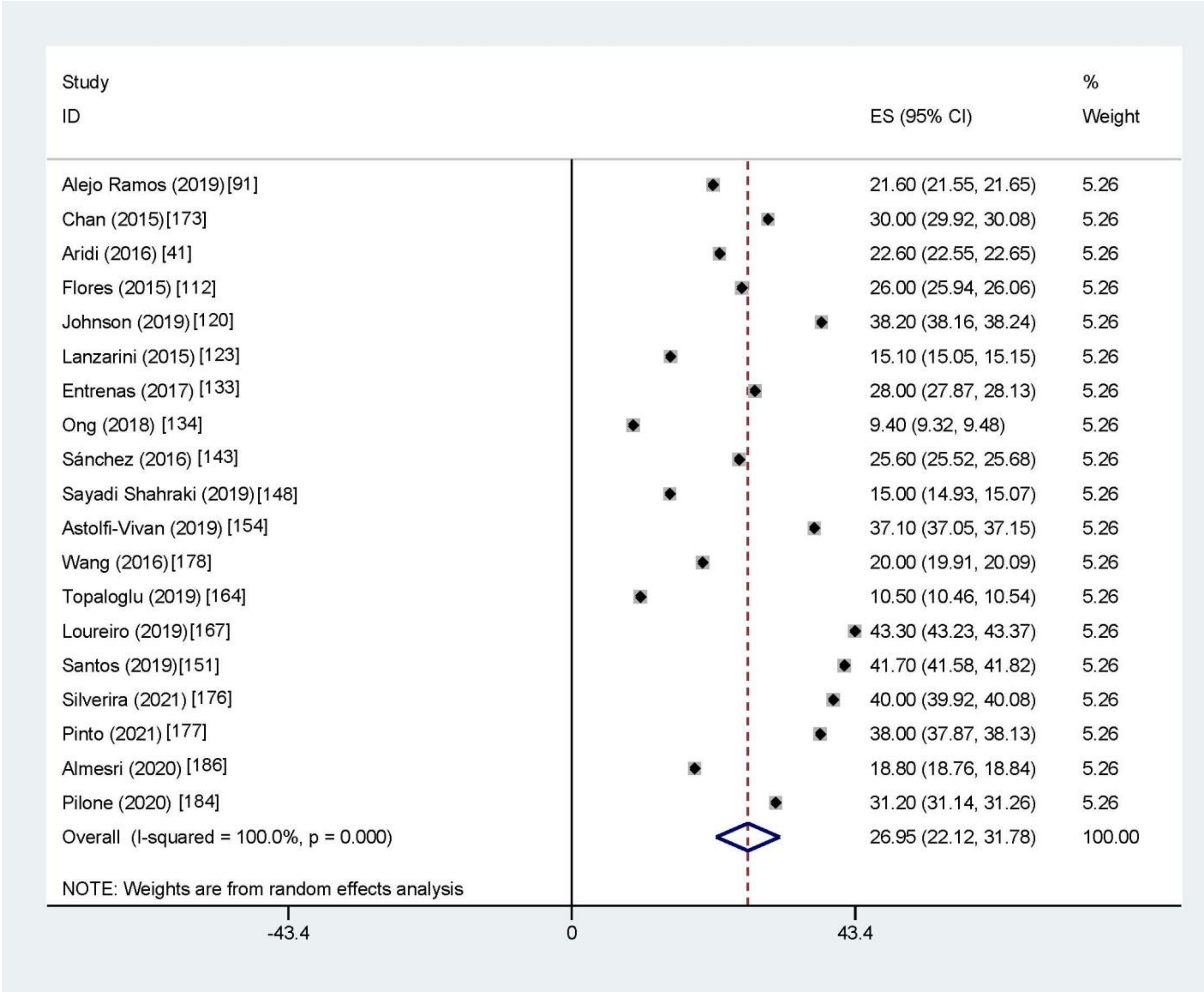
Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023



Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

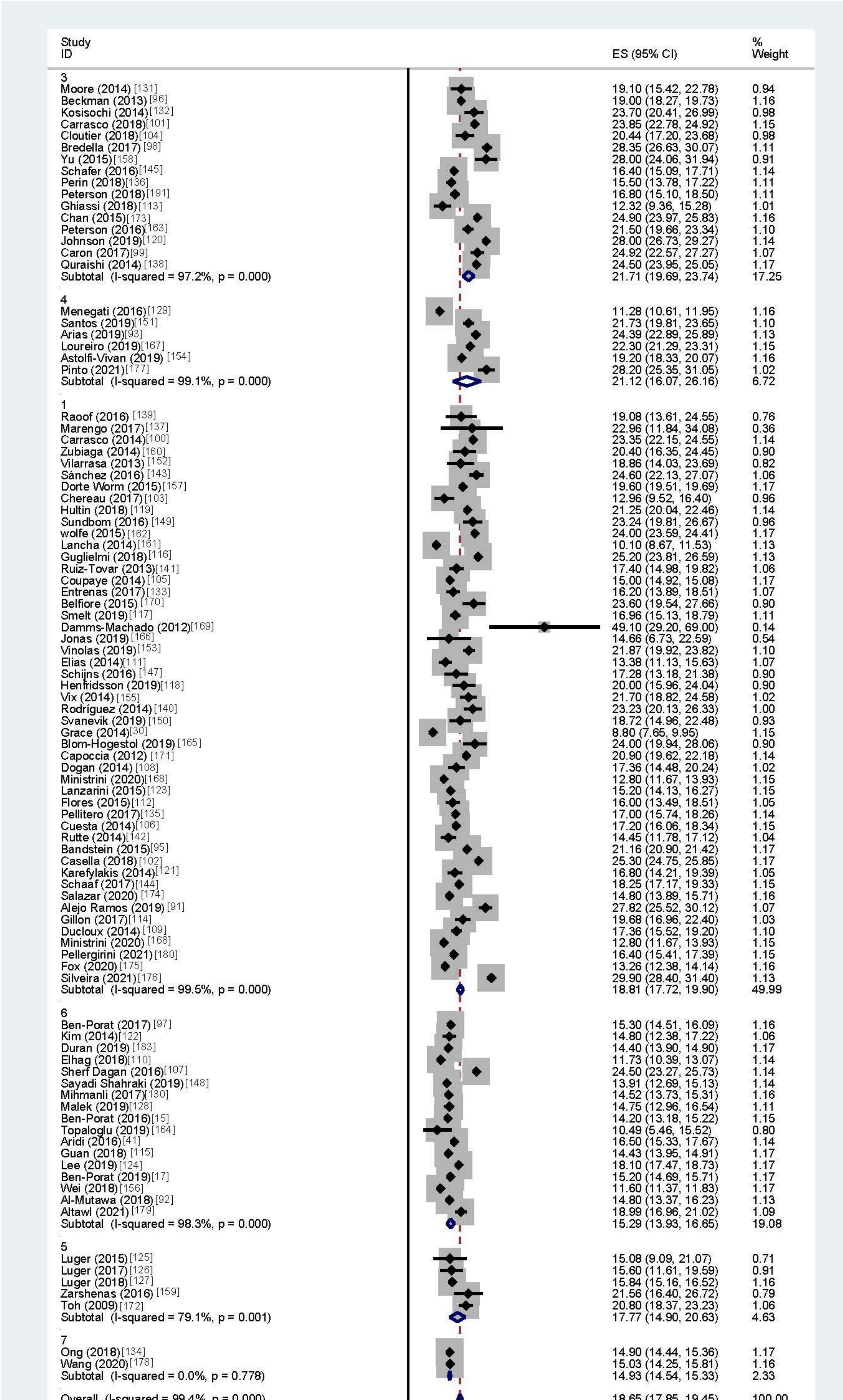


Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

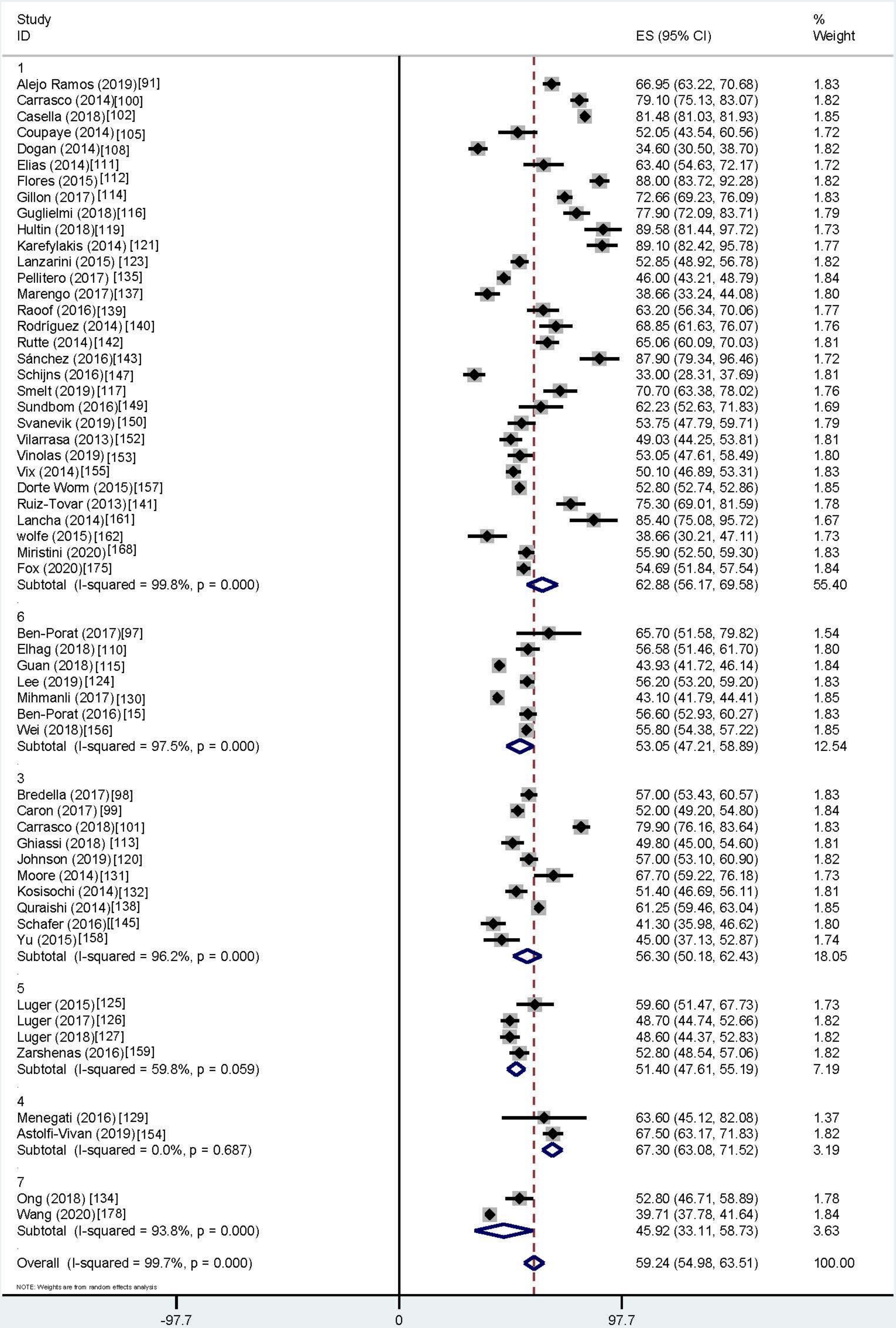


Accepted

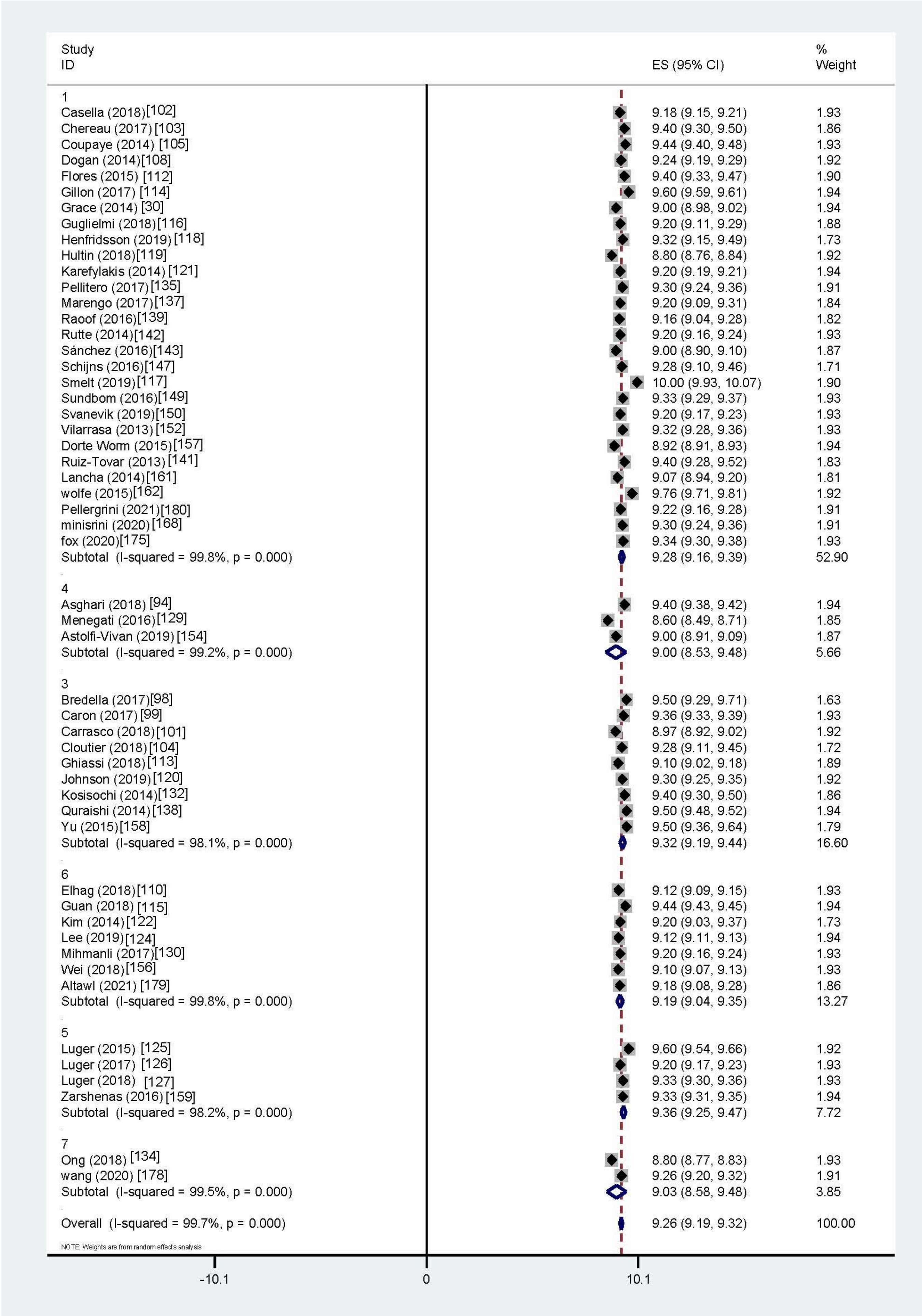
Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023



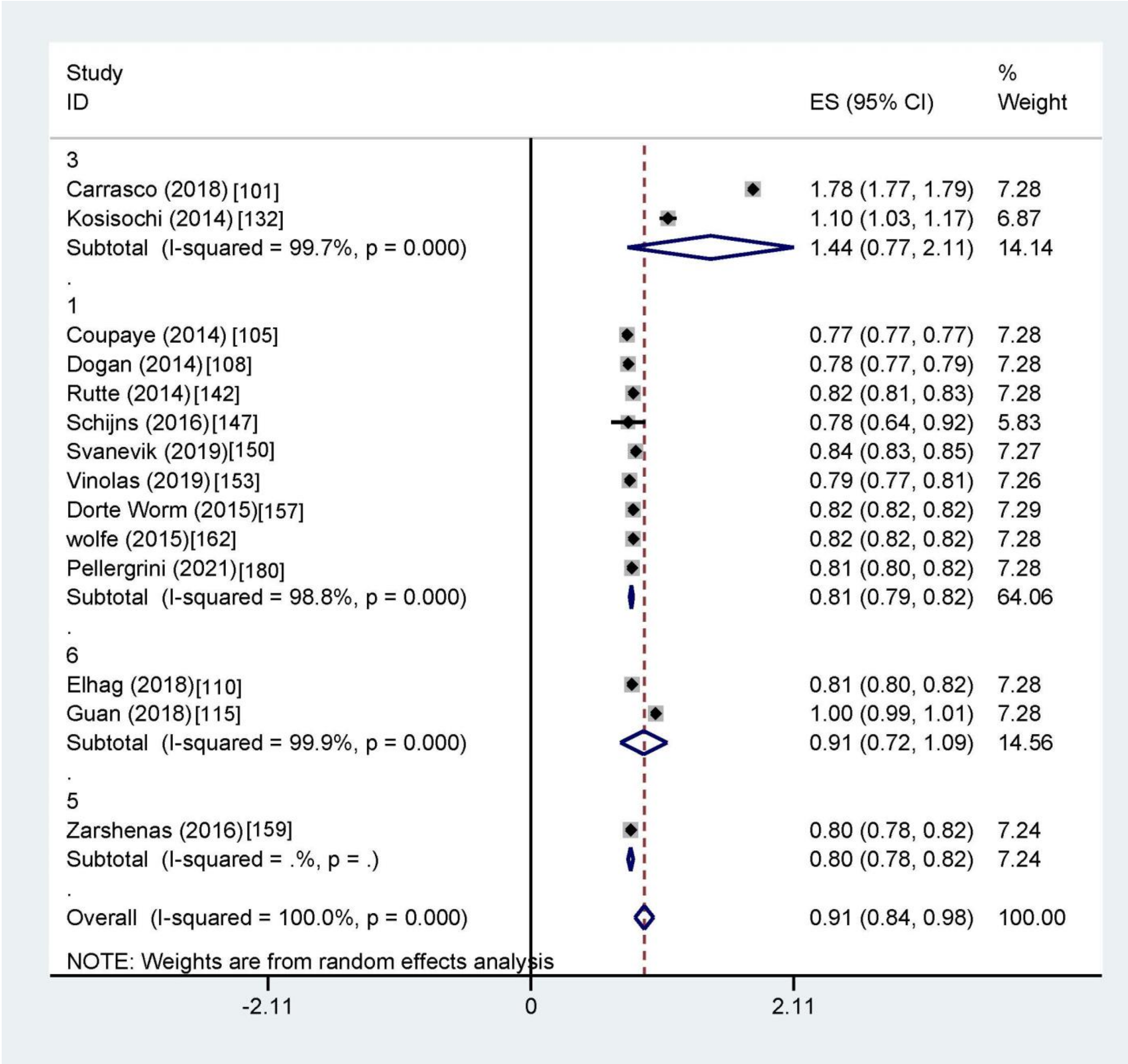
Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023



Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023



Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023



Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Author	Year	Country	Sex	Age (Year)	BMI	Sample size	Outcome
Alejo Ramos et al. [91]	2019	Spain	M/F	43.07	49.82	321	Vit D, PTH
Al-Mutawa et al. [92]	2018	Kuwait	M/F	35	46.1	1793	Vit D
Arias et al. [93]	2019	Argentina	M/F	40.25	43.74	169	Vit D
Asghari et al. [94]	2018	Iran	M/F	37.8	37.8	2008	Ca
Bandstein et al. [95]	2015	Switzerland	M/F	42.8	45.2	210	Vit D
Beckman et al. [96]	2013	USA	F	48	48	29	Vit D
Ben-Porat al. [97]	2017	Israel	M/F	39.8	45.2	27	Vit D, PTH
Bredella et al. [98]	2017	United States	M/F	49	43.9	21	Ca, Vit D, PTH
Caron et al. [99]	2017	Canada	M/F	48	48.1	537	Ca, Vit D, PTH
Carrasco et al. [100]	2014	Chile	F	33.5	40	43	Vit D, PTH
Carrasco et al. [101]	2018	USA	F	35	39.1	58	Ca, Mg, Vit D, PTH
Casella et al. [102]	2018	Italy	M/F	37	44.34	226	Ca, Vit D, PTH
Chereau et al. [103]	2017	France	M/F	46	44.9	48	Vit D
Cloutier et al. [104]	2018	Canada	M/F	40.4	45.9	20	Ca, Vit D, PTH
Coupaye et al. [105]	2014	France	M/F	45	48.5	86	Ca, Mg, Vit D, PTH
Cuesta et al. [106]	2014	Spain	M/F	42.28	44.1	178	Vit D
Sherf Dagan et al. [107]	2016	Israel	M/F	41.9	42.3	100	Vit D
Aridi et al. [41]	2016	Lebanon	M/F	39.7	43.1	257	Vit D
Dogan et al. [108]	2014	Netherlands	F	74	44.8	148	Ca, Mg, Vit D, PTH
Ducloux et al. [109]	2014	France	M/F	55.9	32.5	547	Vit D
Elhag et al. [110]	2018	Qatar	M/F	16	46.04	79	Ca, Mg, Vit D, PTH
Elias et al. [111]	2014	Finland	M/F	NS	42.65	63	Vit D, PTH
Flores et al. [112]	2015	Spain	M/F	44	46	176	Ca, Vit D, PTH
Ghiassi et al. [113]	2018	USA	M/F	50.8	48.4	96	Ca, Vit D, PTH
Gillon et al. [114]	2017	Norway	M/F	41	45.3	336	Ca, Vit D, PTH
Guan et al. [115]	2018	China	M/F	32	40.11	120	Ca, Mg, Vit D, PTH

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Guglielmi et al. [116]	2018	Italy	M/F	40	48.5	42	Ca, Vit D, PTH
Smelt et al. [117]	2019	Netherlands	M/F	45	42.6	100	Ca, Vit D, PTH
Henfridsson et al. [118]	2019	Sweden	M/F	16.5	45.5	85	Ca, Vit D
Hultin et al. [119]	2018	Sweden	M/F	40	54.5	20	Ca, Vit D, PTH
Johnson et al. [120]	2019	Minnesota	M/F	43	45.75	468	Ca, Vit D, PTH
Karefylakis et al.[121]	2014	Sweden	M/F	49	43.4	293	Ca, Vit D, PTH
Kim et al. [122]	2014	Korea	M/F	45.8	32.9	33	Ca, Vit D
Lanzarini et al. [123]	2015	Spain	M/F	45.7	43	164	Vit D, PTH
Lee et al. [124]	2019	Singapore	M/F	40.6	42.4	577	Ca, Vit D, PTH
Luger et al. [125]	2015	Austria	M/F	46	45.4	50	Ca, Vit D, PTH
Luger et al. [126]	2017	Austria	M/F	42.2	43.8	50	Ca,Vit D, PTH
Luger et al. [127]	2018	Austria	M/F	42.2	43.8	50	Ca, Vit D, PTH
Malek et al. [128]	2019	Iran	M/F	37.4	45.7	170	Vit D
Menegati et al. [129]	2016	Brazil	F	38.9	52.2	25	Ca, Vit D, PTH
Mihmanli et al. [130]	2017	Turkey	M/F	37	49	119	Ca, Vit D, PTH
Moore et al. [131]	2014	USA	F	40.5	46.2	11	Vit D, PTH
Kosisochi et al. [132]	2014	USA	F	44.6	46.7	34	Ca, Mg, VitD, PTH
Entrenas et al. [133]	2017	Spain	M/F	41	45.5	46	Vit D
Ong et al. [134]	2018	Singapore	M/F	40.4	40.1	111	Ca, Vit D, PTH
Pellitero et al. [135]	2017	Spain	M/F	49.3	46.7	176	Ca, Vit D, PTH
Perin et al. [136]	2018	USA	M/F	43.1	46.2	47	Vit D
Marengo et al. [137]	2017	Spain	F	46.3	42.9	38	Ca, Vit D, PTH
Ben-Porat et al. [15]	2016	Israel	M/F	36.5	42.9	192	Vit D, PTH
Quraishi et al. [138]	2014	USA	M/F	47.2	47.2	385	Ca, Vit D, PTH
Raoof et al. [139]	2016	Sweden	F	41.6	44.5	32	Ca, Vit D, PTH
Rodríguez et al. [140]	2014	Spain	M/F	44.18	46.8	110	Vit D, PTH
Ruiz-Tovar et al. [141]	2013	SPAIN	M/F	43.6	51.2	42	Ca, Vit D, PTH
Rutte et al. [142]	2014	Netherlands	M/F	42.7	46.2	200	Ca, Mg, Vit D, PTH

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Sánchez et al.[143]	2016	Chile	F	36	43.1	103	Ca, Vit D, PTH
Schaaf et al. [144]	2017	France	M/F	41.7	40.9	258	Vit D
Schafer et al. [145]	2016	USA	M/F	45.4	44.7	33	Vit D, PTH
Schijns et al. [146]	2018	Netherlands	M/F	46	44.2	569	Vit D
Schijns wt al. [147]	2016	Netherlands	M/F	47.1	44.7	75	Ca, Mg, Vit D, PTH
Shahraki et al. [148]		Iran	M/F	35.6	43.8	33	Vit D
Sundbom et al. [149]	2016	Sweden	M/F	39.7	42.7	26	Ca, Vit D, PTH
Svanevik et al.[150]	2019	Norway	M/F	40	53.4	56	Ca, Mg, Vit D, PTH
Santos et al. [151]	2018	Brazil	F	45	31.7	49	Vit D
Vilarrasa et al. [152]	2013	Spain	F	47.7	47.9	33	Ca, Vit D, PTH
Vinolas et al. [153]	2019	France	M/F	44	45.4	58	Mg, Vit D, PTH
Vivan et al. [154]	2019	Brazil	M/F	44.9	49.3	291	Ca, Vit D, PTH
Vix et al. [155]	2014	France	M/F	35.1	46	50	Vit D, PTH
Wei et al. [156]	2018	Taiwan	M/F	34.2	39.4	1470	Ca, Vit D, PTH
Worm et al. [157]	2015	Denmark	M/F	43.3	47.2	417	Ca, Mg, Vit D, PTH
Yu et al. [158]	2015	USA	M/F	47	45	30	Ca, Vit D, PTH
Zarshenas et al. [159]	2016	Australia	M/F	51.9	42.8	91	Ca, Mg, Vit D, PTH
Zubiaga Toro et al. [160]	2014	Spain	F	47.7	50.4	50	Vit D
Lancha et al. [161]	2014	Spain	M/F	44	42	40	Ca, Vit D, PTH
Wolf et al. [162]	2015	Germany	M/F	46	45	38	Ca, Mg, Vit D, PTH
Peterson et al. [163]	2016	USA	M/F	42.6	46.3	58	Vit D
Topaloglu et al. [164]	2019	Turkey	M/F	38	44.3	199	Vit D
Blom-Hogestol et al. [165]	2019	Norway	M/F	50.3	35.6	122	Vit D
Jonas et al. [166]	2019	Poland	M/F	41.49	46.85	55	Vit D
Loureiro et al. [167]	2019	Brazil	M/F	38.86	42.9	223	Vit D
Ben-Porat et al. [17]	2019	Israel	M/F	36.5	42.4	722	Vit D
Ministrini et al. [168]	2020	Italy	M/F	43.5	45.5	152	Vit D
Damms-Machado et al. [169]	2012	Germany	M/F	44	51	54	Vit D

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

Belfiore et al. [170]	2015	Italy	M/F	34.9	45.9	47	Vit D
Capoccia et al. [171]	2012	Italy	M/F	43.9	44.4	138	Vit D
Toh et al. [172]	2009	Australia	M/F	46	51	188	Vit D
Chan et al. [173]	2015	USA	M/F	48	54.1	134	Vit.D
Grace et al. [30]	2014	UK	M/F	44	52.6	118	Vit.D, Ca
Salazar et al. [174]	2020	Portugal	M/F	41	43.6	290	Vit.D
Fox et al. [175]	2020	UK	M/F	48	50	460	Vit.D, Ca, PTH
Silveira et al. [176]	2021	Brazil	M/F	40	41	150	Vit.D
Pinto et al. [177]	2020	Brazil	M/F	38.7	42.3	50	Vit.D
Wang et al. [178]	2020	China	M/F	46	31.37	230	Vit.D, Ca, PTH
Altaw et al. [179]	2021	Saudi Arabia	M/F	31.3	44.95	143	Vit.D, Ca
Pellergini et al. [180]	2021	Italy	M/F	43.2	42.8	200	Vit.D, Ca, Mg
Ballesteros-Pomar et al. [181]	2016	Spain	M/F	43.2	50.1	299	Vit.D
Van der Beek et al. [182]	2015	Netherland	M/F	47.3	45.3	427	Vit.D
Duran et al. [183]	2019	Turkey	M/F	41.5	47.9	73	Vit.D
Pilone et al. [184]	2020	Italy	M/F	34.9	44.3	206	Vit.D
Kessler et al. [185]	2020	Israel	M/F	46.1	42.0	86	Vit.D
Almesri et al. [186]	2020	Bahrain	M/F	33.1	46	314	Vit.D
Lefebvre et al. [9]	2014	France	M/F	40.5	43.2	267	Vit.D
Lin et al. [187]	2011	USA	F	33.8	47.5	20	Vit.D
Moizé et al. [188]	2013	Spain	M/F	45.8	49.5	355	Vit.D
Nath et al. [189]	2019	USA	M/F	46.7	49.3	271	Vit.D
Wang et al. [190]	2016	China	M/F	33.3	39.3	211	Vit.D
Peterson et al. [191]	2018	USA	M/F	43	46.3	265	Vit D

LRYGB: laparoscopic Roux-en-Y RYGB
LSG: Laparoscopic Sleeve Gastrectomy
AGB: Adjustable gastric banding
BPD: Biliopancreatic diversion

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023

Table 2. Subgroup analysis of the mean estimates of serum 25(OH)D, PTH. calcium and magnesium in morbidly obese patients or bariatric surgery candidates based on geographical zones

Subgroup	Included studies	Sample size	Pooled mean estimate	95% confidence interval	Heterogeneity (I^2-%)
Serum 25(OH)D [ng/ml]					
Total	96	18998	18.65	17.85, 19.45	99.4%
Europe	50		18.94	17.86, 20.02	99.5%
North America	16		21.71	19.69, 23.74	97.2%
South America	6		21.12	16.07, 26.16	99.1%
Australia	5		17.77	14.90, 20.63	79.1%
Middle East	17		15.29	13.93, 16.65	98.3%,
South East Asia	2		14.93	14.54-15.33	0.0%
Serum PTH [pg/ml]					
Total	56	11545	59.24	54.98, 63.51	99.7%
Europe	31		62.88	56.17-69.58	99.8%
North America	10		56.3	50.18-62.43	96.2%
South America	2		67.3	63.08-71.52	0.0%
Australia	4		51.4	47.61-55.19	59.8%
Middle East	7		53.05	47.21-58.89	97.5%
South East Asia	2		45.92	33.11-55.73	93.8%
Serum calcium (mg/dl)					
Total	53	13355	9.26	9.19-9.32	99.7%
Europe	28		9.28	9.16, 9.39	99.8%
North America	9		9.32	9.19, 9.44	98.1%
South America	3		9.00	8.53, 9.48	99.2%
Australia	4		9.36	9.25, 9.47	98.2%
Middle East	7		9.19	9.04, 9.35	99.8%,
South East Asia	2		9.03	8.58, 9.48	99.5%
Serum magnesium (mg/dl)					
Total	13	2527	0.91	0.84, 0.98	100.0%
Europe	9		0.81	0.79, 0.82	98.8%
North America	2		1.44	0.77, 2.11	99.7%
South America	-	-	-	-	-
Australia	-	-	-	-	-
Middle East	2		0.91	0.72, 1.09	99.9%
South East Asia	-	-	-	-	-

Accepted Manuscript

Downloaded from http://karger.com/ofa/article-pdf/doi/10.1159/000533828/3992637/000533828.pdf by guest on 01 October 2023