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The prognostic role of obesity is independent of sex in cancer patients treated with immune checkpoint inhibitors: A pooled analysis of 4090 cancer patients

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ABSTRACT

Objective: Recent studies suggest obesity is associated with improved survival of cancer patients treated with immune checkpoint inhibitors (ICIs). We performed this meta-analysis to evaluate the impact of obesity on survival of these patients with regard to the cutoff value of body mass index (BMI) as well as sex.

Methods: Electronic databases including Pubmed, Emabse, and the Cochrane library were systematically searched until April 2019, without language limitation. Clinical studies evaluating the association between BMI and survival of cancer patients treated with ICIs were included. The main endpoints were overall survival (OS) and progression-free survival (PFS). Data from individual studies were extracted by two researchers, independently. RevMan 5.3 and Stata 11 software were used to perform the analysis.

Results: 16 retrospective studies met the inclusion criteria, with a total of 4090 patients. The OS (HR = 0.72, 95% CI: 0.51–1.02; $P = 0.06$) and PFS (HR = 0.67, 95% CI: 0.48–0.95; $P = 0.02$) of the high BMI group were improved compared with the low BMI group. Dose-response analysis showed that the risk of death decreased by 3.6% when the BMI increased every 1 kg/m^2. Subgroup analysis revealed that BMI > 30 was a reliable value for determining significantly better OS (HR = 0.64; 95%CI: 0.43–0.96; $P = 0.03$). The prognostic effect of BMI on OS was significant regardless of gender (For male, HR = 0.73, 95% CI: 0.61–0.86; $P < 0.01$. For female, HR = 0.63, 95% CI: 0.43–0.92; $P = 0.02$).

Conclusions: Obesity is associated with better outcomes in cancer patients treated with ICIs, and this clinical benefit may be independent of sex.

1. Introduction

Recent breakthroughs in immunotherapy have altered the landscape of multiple cancer therapy and are being dramatically applied in clinical practice alone or in combinations with other treatments [1]. Among these approaches of immunotherapy, immune checkpoint inhibitors (ICIs) have been approved for various malignancies [2]. Due to the remarkable duration of response in cancer patients with advanced diseases, ICIs have been the hot topic in clinical immunotherapy researches [2,3]. However, the findings from several clinical studies exhibit that only a limited percentage of these patients can gain treatment benefits from ICIs [4,5]. Therefore, it is important to understand the factors affecting the outcomes of ICIs and identify patients who will response to immunotherapy.

Obesity is defined as excessive fat tissue accumulated in body, and associated with chronic pro-inflammatory state [1,6]. This condition hampers immune status in this population [1,6]. It is reported that obesity has a strong contribution to the occurrences of several cancers and is a negative prognostic factor for cancer development and treatment [1,6]. However, recent clinical evidence has raised a question about this statement in the setting of immunotherapy [3,7–9]. In a cohort analysis, a number of 250 cancer patients who received ICIs treatment were stratified by body mass index (BMI). The findings exhibited that improved efficacy was observed among high BMI patients, as well as the progression free survival and overall survival compared to normal BMI patients [10]. Another study reported a similar result in 170 patients with melanoma [9]. In this study, after dividing patients by BMI, the results found that the progression free survival and overall survival were all improved in patients with BMI > 30 compared with those < 30 [9]. Their findings also suggested sex was a key factor for the prognostic role of BMI, as only men with BMI > 30 showed a significant survival benefit after ICIs treatment [9]. BMI seems to be

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another emerging prognostic factor for immunotherapy regardless of cancer types. Despite most of the current studies suggest a positive connection between improved survival and efficacy of ICIs and high BMI, critical concerns remain regarding the value of BMI and its relationship with sex.

Therefore, we performed this systematic review and meta-analysis, trying to address the questions mentioned above. By searching multiple databases, identifying eligible studies, extracting and combining clinical evidence, this study intended to use meta-analysis method to evaluate the impact of BMI on the efficacy of ICIs as well as the survival of cancer patients, aimed to provide scientific evidence-based basis for clinical application.

2. Material and methods

This meta-analysis was not registered. This study was conducted according to the guideline of the Cochrane Handbook 5.1 [11].

2.1. Search strategy

Electronic databases including Pubmed, the Cochrane library, and Embase were systematically searched to identify potential eligible studies evaluating the association between BMI and outcomes of cancer patients treated with ICIs, without language limitation until April 2019. The main searching terms were body mass index, cancer, and immune checkpoint inhibitor using the detailed search strategy [12]. The references listed in relevant reviews or potential eligible studies of the interested topic were also reviewed to ensure a best inclusion. We contacted the authors of the studies without detailed information to get enough data as possible.

2.2. Inclusion and exclusion criteria

The inclusion criteria were established based on the clinical questions, and listed as following, Study type: randomized controlled trials (RCTs) or retrospective studies; Subjects: patients with solid cancers, especially lung cancer, and melanoma; Interventions: immune checkpoint blockade; Outcomes: primary endpoint was overall survival, and secondary endpoints were progression free survival, objective response, and adverse events.

Exclusion criteria were as following: studies were excluded if they were reviews, animal researches, comments, brief reports, or case reports. Studies without enough data on any of the endpoints were also discarded.

2.3. Study selection and data extraction

Based on the inclusion and exclusion criteria, two reviewers participated in the processes of study selection and data extraction. The titles were screened at first and studies were discarded if they met the exclusion criteria. Next, the abstracts of the remaining studies were reviewed to check if they met the inclusion criteria. The full-texts of the left studies were further viewed to find out if they had interested data or not. Then the relevant data were extracted by two reviewers, independently. If there was any disagreement with regard to the included study or extracted data, a third reviewer was invited to resolve it.

Data of baseline characteristics such as first author, publication year, patient number, age, sex, disease, BMI value, and treatment were extracted. Main outcome indicators were OS, PFS, response, and adverse reactions. The BMI was calculated using the body weight expressed in kilograms to squared height expressed in meters (BMI = body weight kg/height m^2) [1]. In general, BMI ranges from 18.5 to 24.9 kg/m^2 indicates normal weight, from 25 to 29.9 kg/m^2 means overweight, and shows obesity if it is over 30 kg/m^2. In this meta-analysis, we defined low BMI if it is < 25 kg/m^2, or high BMI if it is above 25 kg/m^2.

2.4. Quality assessment

The quality of the included studies was evaluated according to the quality evaluation criteria of the Newcastle-Ottawa Scale (NOS) which was used for assessing the quality of non-randomized studies in meta-analyses [13]. The main evaluation aspects are selection, comparability and outcome. Selection part includes A: representativeness of cases, B: selection of controls, C: exposure ascertainment, and D: demonstration that outcome of interest was not present at start of study. Comparability part includes E: comparable on confounders. Outcome part includes F: outcome assessment, G: adequate follow-up, and H: loss to follow-up rate. A maximum of one star can be awarded to each item of the selection and outcome parts. Comparability can gain two stars at most. If the study satisfies all quality evaluation criteria, there is low possibility of bias and will be awarded with nine stars; if any one of the evaluation criteria of the study is not satisfied, the possibility of bias is moderate; If more than two of the evaluation criteria are completely unsatisfactory, there is a high probability of bias, which is less than five stars.

2.5. Statistical analysis

Meta-analysis was performed using the Review Manager 5.3 and STATA 11 software. We used different values of BMI to define high versus low BMI group. We defined low BMI group if BMI < 25 or BMI < 30, otherwise it is considered as high BMI group. The combined hazard ratio (HR) and its 95% confidence interval (CI) were used for the survival benefit assessment. The risk ratio (RR) and its 95% CI were used to estimate the effect of obesity on clinical response and risk of adverse events. A dose response analysis was performed to determine the relationship between BMI increase and risk of death after ICIs treatment. I^2 was calculated to test for heterogeneity between studies. If there was no statistical or clinical heterogeneity between the studies ($P > 0.1$, $I^2 < 50\%$), the fixed effect was used for meta-analysis; if there was moderate or high statistical heterogeneity among the included studies but no clinical heterogeneity ($P \leq 0.1$, $I^2 \geq 50\%$), a subgroup analysis was performed. Sensitivity analysis was performed by excluding individual studies one by one.

3. Results

3.1. Search results

The search flow chart of the literature is shown in Fig. 1. The literature search resulted in 531 studies. After checking and removing the irrelevant studies, 19 studies were obtained. The full-texts of the remaining 19 studies were further reviewed and finally 16 studies [9,10,14–27] were included.

3.2. Baseline characteristics of included studies

The general information of all studies is shown in Table 1. All of them were retrospective studies. There were 2022 male and 2068 female patients. The age of these patients ranged from 22 to 92 years. Non-small cell lung cancer was the most reported cancer type. These studies were distributed in Asia, North America and Europe. All studies used BMI to group patients at various BMI values. The cut-off values of BMI included in the eligible studies varied, ranging from 18.5 to 30 kg/m^2. Age, sex ratio, and immunotherapy were similar between the studies (Table 1).

3.3. Quality assessment result

Two reviewers read the full text of the literatures and evaluated their quality based on the NOS criteria, independently. After assessment, a five-star was given to one study; three studies were regarded as six-star score; three studies got eight-star score; and the rest of the

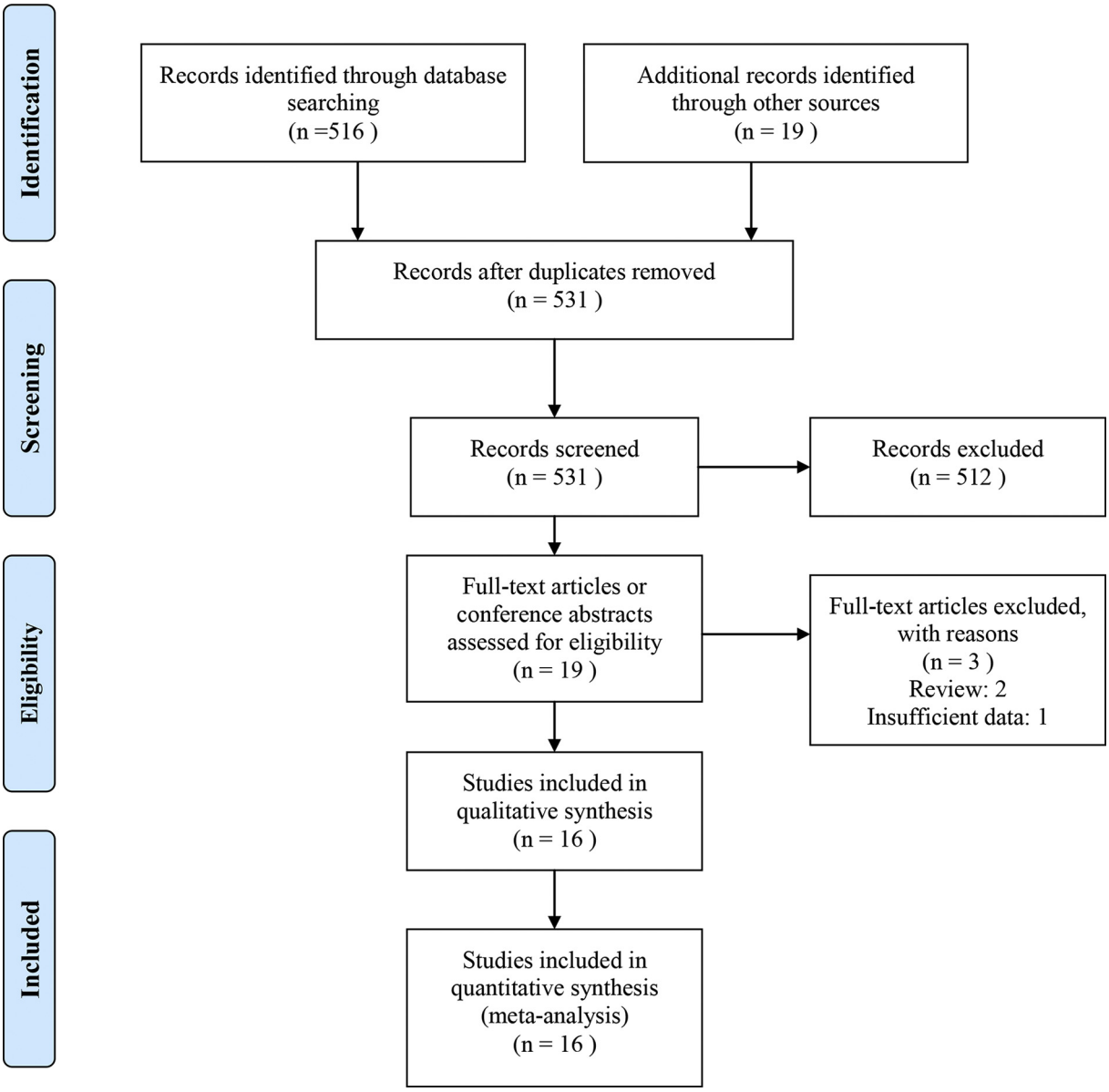

Fig. 1. Flow diagram of identifying eligible studies.

Table 1
Baseline characteristics of included studies.

Author	Year	Number	Region	Male(%)	Age	Cancer	Treatment	BMI cutoff value	Outcomes
Richtig	2018	76	Australia	46(60.53)	NR	Metastatic melanoma	Ipilimumab	25	OS, PFS, ORR
McQuade	2018	538	North America	349(64.87)	23–88	Metastatic melanoma	Immunotherapy	25, 30	OS, PFS, ORR
Kondo	2019	39	Asia	24(61.54)	28–84	Metastatic melanoma	Nivolumab	20	OS, PFS
Wang	2019	250	North America	114(45.6)	23–91	Multiple	Immunotherapy	30	OS, PFS
Zhi	2018	703	North America	NR	NR	Advanced NSCLC	Nivolumab and pembrolizumab	25, 30	OS
Dizman	2018	235	North America	172(73.19)	33–90	Advanced RCC	Immunotherapy	25	OS
Gomes	2017	187	South America	108(57.75)	27–89	Metastatic melanoma	Ipilimumab	25	PFS
Ibrahimi	2018	198	North America	NR	62	Multiple	Immunotherapy	30	OS, PFS
Cortellini	2019	976	Europe	663(67.93)	24–92	Multiple	Immunotherapy	25	OS, PFS, TTF,ORR
Heidelberger	2017	68	Europe	33(48.53)	22–91	Metastatic melanoma	Immunotherapy	25	ORR
Labomascus	2018	162	North America	65(40.12)	68	Advanced NSCLC	Immunotherapy	24.69	OS, PFS, ORR
Shiroyama	2018	201	Asia	135(67.16)	27–87	Advanced NSCLC	Nivolumab	18.5	PFS
Taniguchi	2017	201	Asia	135(67.16)	27–87	Advanced NSCLC	Nivolumab	20	PFS
Dumenil	2018	67	Europe	46(68.66)	68.5	Advanced NSCLC	Nivolumab	18.5	OS, PFS, ORR
Lalani	2019	147	North America	104(70.75)	NR	Advanced RCC	Immunotherapy	25	OS, ORR
Bergerot	2019	42	North America	28(66.67)	49–84	Advanced RCC	Immunotherapy	25	OS, ORR

Abbreviation: BMI, body mass index; NR, not reported; OS, overall survival; PFS, progression free survival; ORR, overall response rate; NSCLC, non-small cell lung cancer; RCC, renal cell carcinoma; TTF, time to treatment failure.

Table 2
Quality assessment of included studies using the NOS criteria.

Author	Year	Selection				Comparability	Outcome			Score
		A	B	C	D	E	F	G	H	
Richtig	2018	☆	☆	☆	☆	☆☆	☆	☆	☆	9
McQuade	2018	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Kondo	2019	☆	☆	☆		☆☆	☆	☆	☆	8
Wang	2019	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Zhi	2018	☆	☆	☆	☆	☆	☆			6
Dizman	2018	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Gomes	2017	☆	☆			☆☆	☆			5
Ibrahimi	2018	☆	☆		☆	☆☆	☆			6
Cortellini	2019	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Heidelberger	2017	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Labomascus	2018	☆	☆	☆		☆☆	☆	☆	☆	8
Shiroyama	2018	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Taniguchi	2017	☆	☆	☆		☆☆	☆	☆	☆	8
Dumenil	2018	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Lalani	2019	☆	☆	☆		☆☆	☆			6
Bergerot	2019	☆	☆	☆	☆	☆☆	☆	☆	☆	9

Note: Selection part includes A: representativeness of cases, B: selection of controls, C: exposure ascertainment, and D: demonstration that outcome of interest was not present at start of study. Comparability part includes E: comparable on confounders. Outcome part includes F: outcome assessment, G: adequate follow-up, and H: loss to follow-up rate. The total score is equal to the total number of stars.

studies were awarded with maximum of stars. The most common reasons lowering the quality of the included studies were item D, G and H. It was difficult to judge these items as the studies did not provide enough information of them. Overall, most of the studies were considered to be moderate or low risk of biasTable 2.

3.4. Results of meta-analysis

3.4.1. Overall survival

To evaluate the association between BMI and OS, we extracted the HR of high versus low BMI on OS from nine individual studies [9,10,14,16,19,20,25–27]. Among them, two [9,14] reported survival results from metastatic melanoma, two [16,25] from advanced non-small cell lung cancer(NSCLC), two [26,27] from advanced renal cell carcinoma(RCC), and three [10,19,20] from multiple cancers. As indicated by the heterogeneity analysis, we used random effect model (I^2 = 93%). As shown in Fig. 2A, the risk of mortality was decreased by 28% in patients with high BMI (≥18.5 kg/m^2) when compared with low BMI(< 18.5 kg/m^2) group (HR = 0.72, 95% CI: 0.51–1.02; P = 0.06). Next, we performed a subgroup analysis based on the cut-off values of BMI. These values were 25 and 30 kg/m^2. The combined HR was 0.72(95% CI: 0.50–1.03; P = 0.07) when using 25 kg/m^2 for grouping and it was 0.64 (95% CI, 0.43–0.96; P = 0.03) when using 30 kg/m^2 as the cut-off value (Fig. 2B). The sensitivity analysis was performed to test the reliability of this finding (Fig. 6), and the result

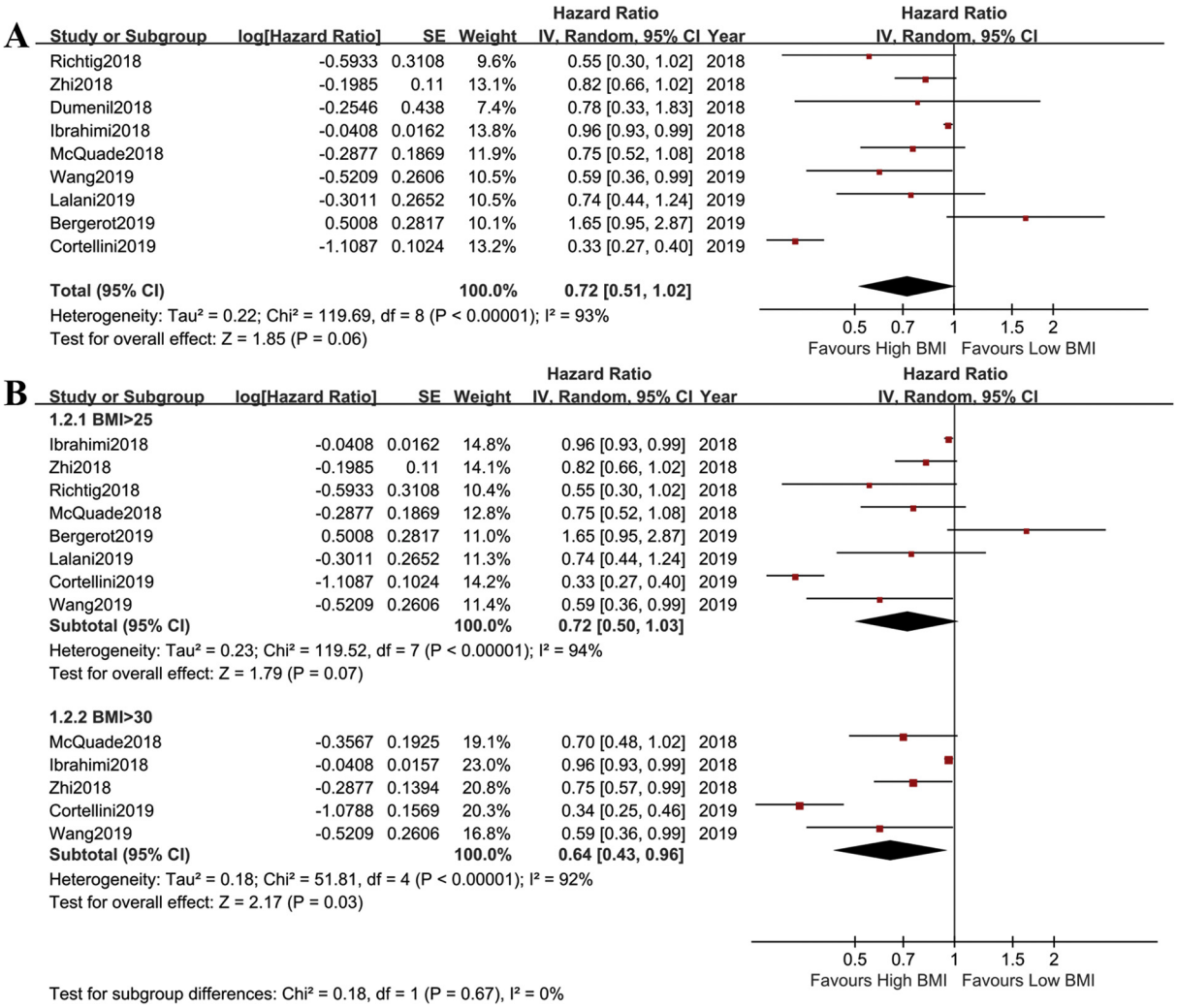

Fig. 2. The association between BMI and OS in cancer patients treated with ICIs. A, overall effect of high BMI versus low BMI on OS; B, subgroup analysis of OS based on BMI values.

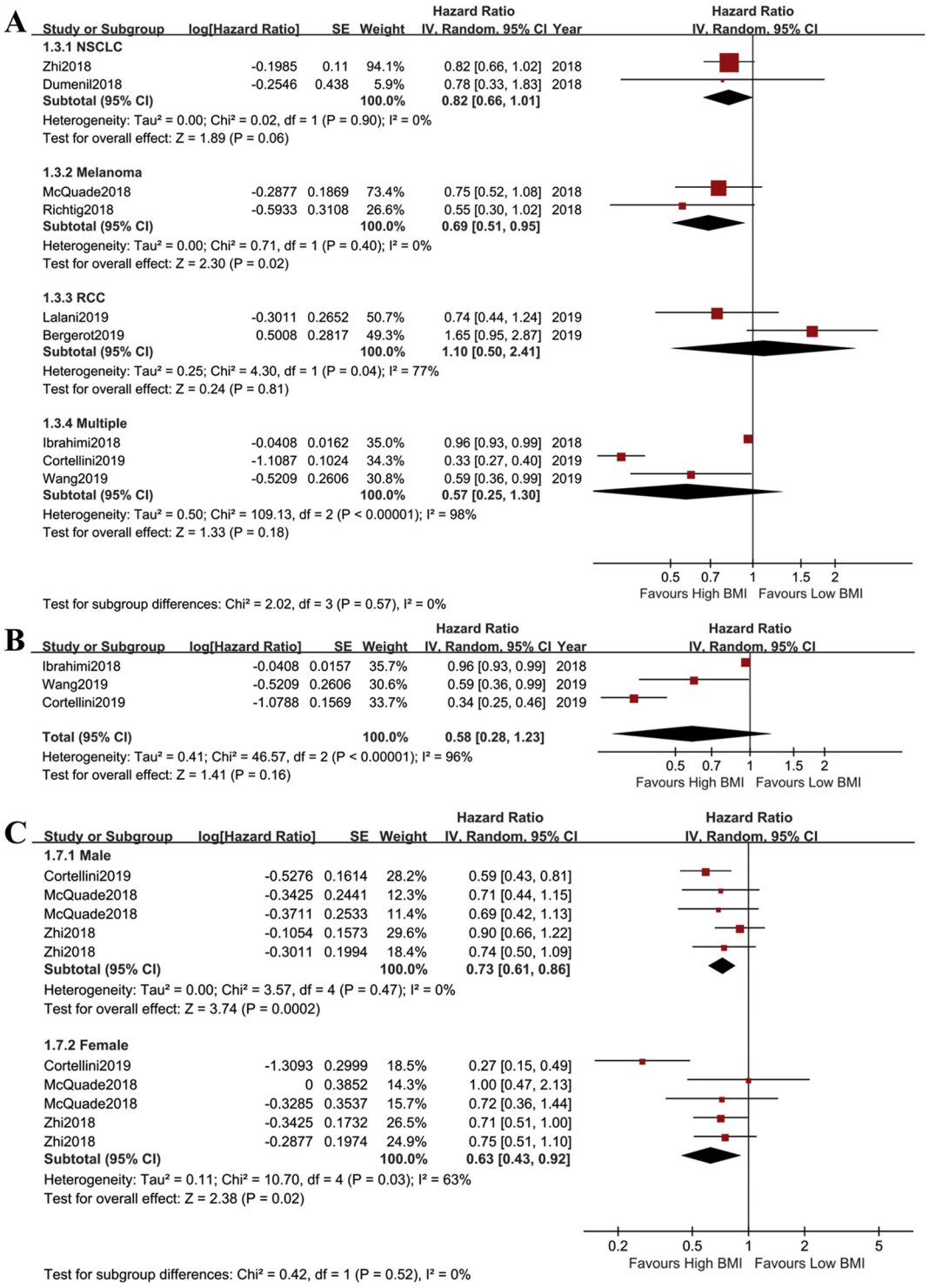

Fig. 3. Subgroup analyses of the relationship between BMI and OS in ICIs treated cancer patients. A, subgroup analysis based on cancer type; B, subgroup analysis based on BMI value and cancer type; C, subgroup analysis based on gender.

showed all the studies were located within the confidential interval.

A subgroup analysis was performed based on cancer types. The subgroups included NSCLC [16,25], melanoma [9,14], RCC [26,27], and multiple cancer [10,19,20]. The random effect model was used as indicated by the heterogeneity test (I^2 > 50%). The results showed that all the cancer patients with high BMI expected to have a lower risk of death after ICIs treatment except those with RCC (Fig. 3A). For patients with advanced melanoma, the death risk was significantly reduced (HR = 0.69; 95% CI: 0.51–0.95; P = 0.02). For RCC patients, the ICIs treatment did not result in an improvement in OS (HR = 1.10; 95% CI: 0.50–2.41; P = 0.81). There was enough number of studies only for multiple cancer based subgroup analysis when using 30 kg/m^2 as the cut-off value (Fig. 3B). The combined result showed that patients with BMI > 30 kg/m^2 had a better OS than those with low BMI (HR = 0.58, 95% CI: 0.28–1.23; P = 0.16), though it was not significant.

The above results suggested that BMI had the potential to be a prognostic factor for cancer patients treated with ICIs. Next, we tried to find out the influence of sex on this effect. By combing the current data

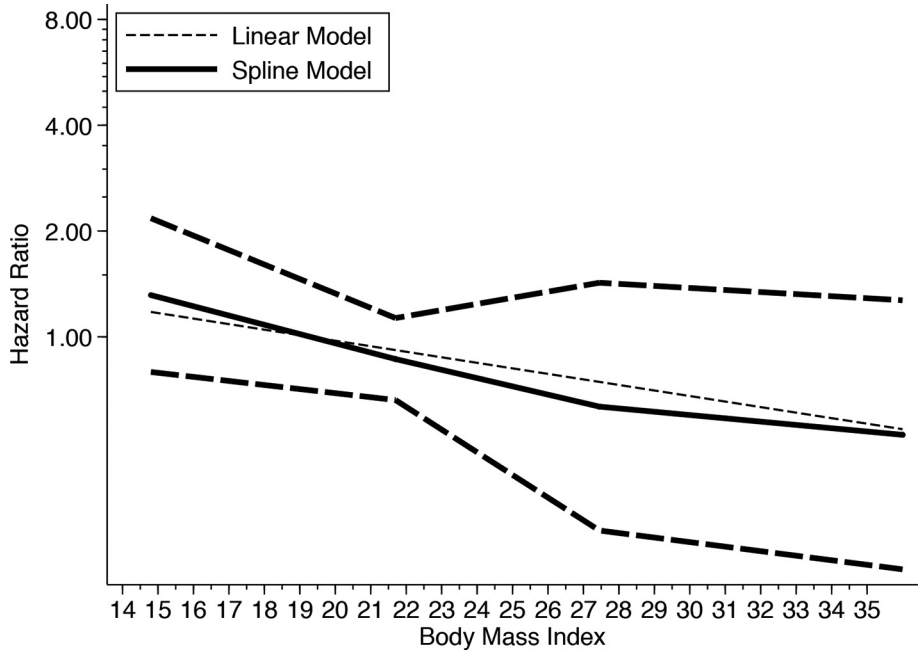

Fig. 4. Dose-response meta-analysis of the association between BMI values and OS.

we had, the pooled results from three studies [9,16,20] exhibited that the overall HR for male was 0.73(95%CI: 0.61–0.86; $P < 0.01$) and it was 0.63(95%CI, 0.43–0.92; $P = 0.02$) for female, suggesting men and women cancer patients with high BMI($\geq$25kg/m^2) shared a similar beneficial efficacy from ICIs. After excluding the study [20] causing significant heterogeneity, the result was still significant for female (HR = 0.75, 95% CI: 0.60–0.94; $P = 0.01$).

We performed a dose-response meta-analysis to further explore the relationship between BMI and OS. A total of 3 studies [9,16,20] with 5 datasets were included in this dose-response meta-analysis. Four intervals of BMI were used as following: $\leq$18.5, 18.5–24.99, 25–29.99 and $\geq$30kg/m^2. As illustrated in Fig. 4, a linear association between BMI and risk of death was found ($P < 0.01$). A decreased mortality of 0.036 (95%CI: -0.005 – -0.067; $P = 0.022$) for each 1 kg/m^2 increase in BMI was observed in this meta-analysis (Fig. 4).

3.4.2. Progression free survival

The connection between BMI and PFS was reported in eight studies [9,10,14,15,19,20,24,25]. As shown in Fig. 5A, the risk of disease progression decreased by 33% in patients with high BMI compared to low BMI group (HR = 0.67, 95% CI: 0.48–0.95; $P = 0.02$). A subgroup analysis was performed based on cancer type. The random effect model was used as there was a high risk of heterogeneity ($I^2 > 50\%$). The pooled data (Fig. 5B) showed that all the cancer patients with high BMI expected to have a lower risk of disease progression after ICIs treatment (For NSCLC, HR = 0.75, $P = 0.09$; For Melanoma, HR = 0.62, $P = 0.14$; For multiple cancer, HR = 0.65, $P = 0.15$). The sensitivity analysis was performed to test the reliability of this finding (Fig. 6B), and the result showed all the studies were located within the confidential interval.

3.4.3. Overall response

Only two studies [20,26] presented the response data. The objective response rate(ORR) was 228/585(38.97%) in high BMI group whereas it was 118/538(21.93%) in low BMI group. Cancer patients with high BMI seemed to have a better anti-cancer response from ICIs compared to low BMI population. However, as shown in Fig. 5C, a non-significant difference in ORR was found between high versus low BMI groups with these limited data (OR = 1.53, 95% CI: 0.47–4.99; $P = 0.48$).

3.4.4. Adverse events

There were four studies [14,20,21,25] showed the incidence of adverse events among cancer patients with different BMI (Fig. 5). The combined result suggested high BMI patients had a significantly higher risk of developing adverse events compared to those with low BMI (OR = 2.91, 95%CI: 1.39–6.11; $P = 0.005$).

3.5. Assessment of publication bias

The Funnel plots are shown in Fig. 6C and D. The Egger's regression test did not find significant publication biases among the analyses of BMI and overall survival ($P = 0.205$) and progression free survival ($P = 0.106$). For the analysis on BMI and overall survival in the dose-response group, the test suggested the probability of publication bias was significant ($P < 0.05$).

4. Discussion

This study collected relevant literature about the connection between BMI and treatment outcomes in multiple cancer patients treated with ICIs in recent years, and used evidence-based meta-analysis to explore the correlation between the value of BMI and the survival of cancer patients with ICIs therapy. By pooling individual data, it was found that cancer patients with high BMI had a reduced risk of mortality than that in patients with low BMI, and the difference was statistically significant. Dose response analysis revealed that the risk of death gradually decreased with the increase in BMI. It was further observed that 30(kg/m^2) was a reliable cut-off value for prognosis regardless of cancer types. In addition, the prognostic role of BMI was independent of sex. Meta-analysis also showed that the PFS and ORR in cancer patients with high BMI were also improved. Together, these results suggested that BMI could be used as a marker for the prognosis of cancer patients treated with ICIs.

BMI has been widely used to define obesity [28]. It is considered overweight if the BMI ranges from 25 to 29.9 kg/m^2 and it is obesity if the BMI exceeds 30 kg/m^2. In most of the included studies (9/16), they used 25 kg/m^2 as the value to define high or low BMI group. Four used 30 kg/m^2 to categorize high versus low BMI groups. Not all of these BMI values were able to distinguish cancer patients who could benefit from ICIs. The results showed the HR for OS was 0.72 for BMI > 25

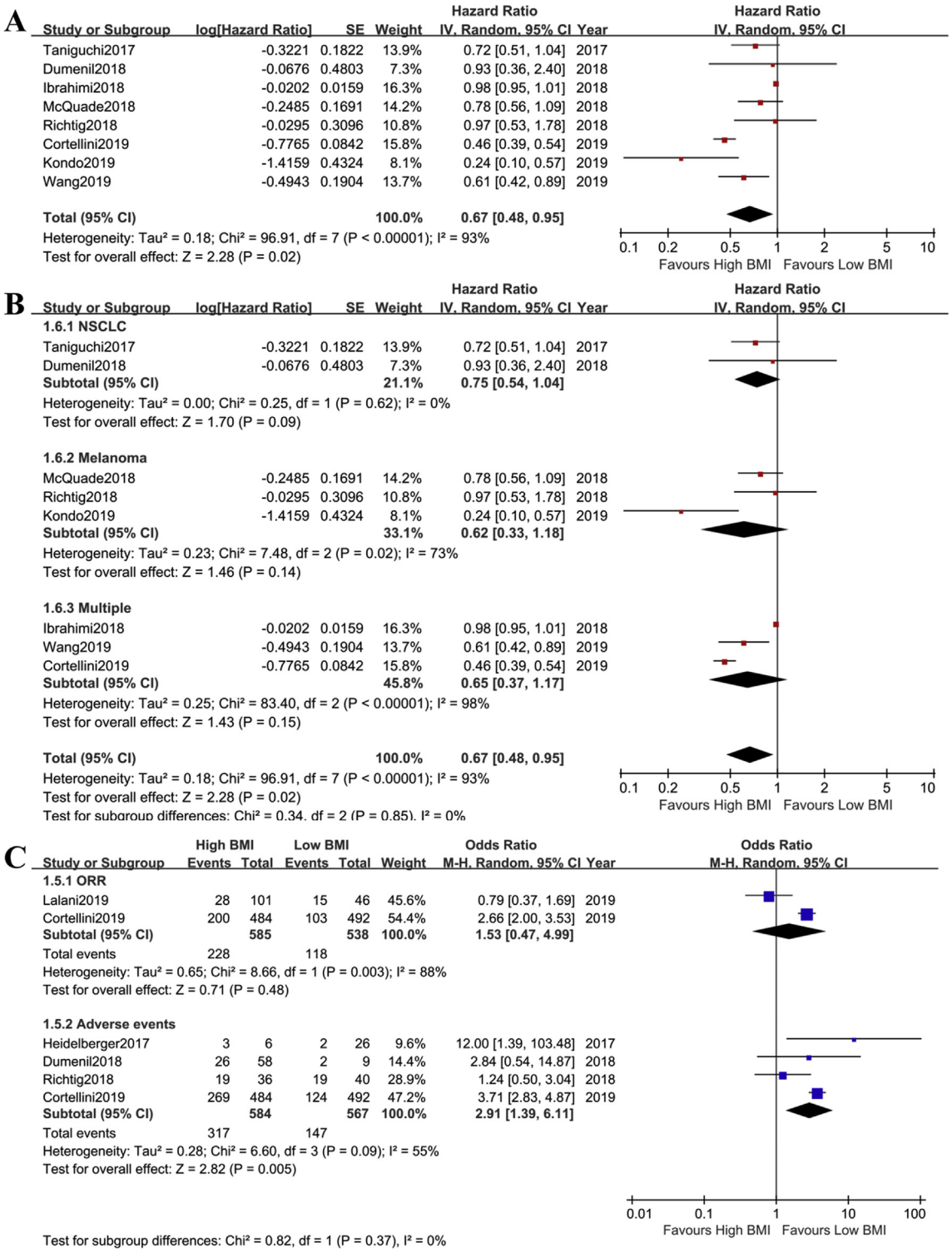

Fig. 5. The impact of BMI on PFS, ORR and adverse events. A, the overall effect of BMI on PFS; B, the subgroup analysis of PFS based on cancer type; C, the association between BMI and ORR, and adverse events.

kg/m^2, and 0.64 for BMI > 30 kg/m^2. It is not well determined whether the risk of death is further decreased if the BMI value continues to rise. A recent study [29] examined the association between BMI values and clinical benefits of ICIs in patients with advanced melanoma. The authors found that obesity was a favorable factor restricted to these patients with BMI ranged from 25 to 35 kg/m^2 [29]. This was in accordance with our results of dose-response analysis that showed a statistical significance even if the HR was still < 1. For patients with BMI ≥ 35 kg/m^2, there was no statistically significant difference with regard to OS (HR = 0.42; P = 0.238) [29]. Due to the limited number of patients, it is not reliable to determine 35 kg/m^2 is the optimal value of BMI to identify patients who are not candidates to be treated with ICIs [29]. However, it seems that cancer patients with BMI ranging from 25 to 35 kg/m^2 could obtain more clinical benefits from ICIs.

From our pooled analysis, it was suggested that the improvement in survival was independent of cancer type except for RCC. Three studies

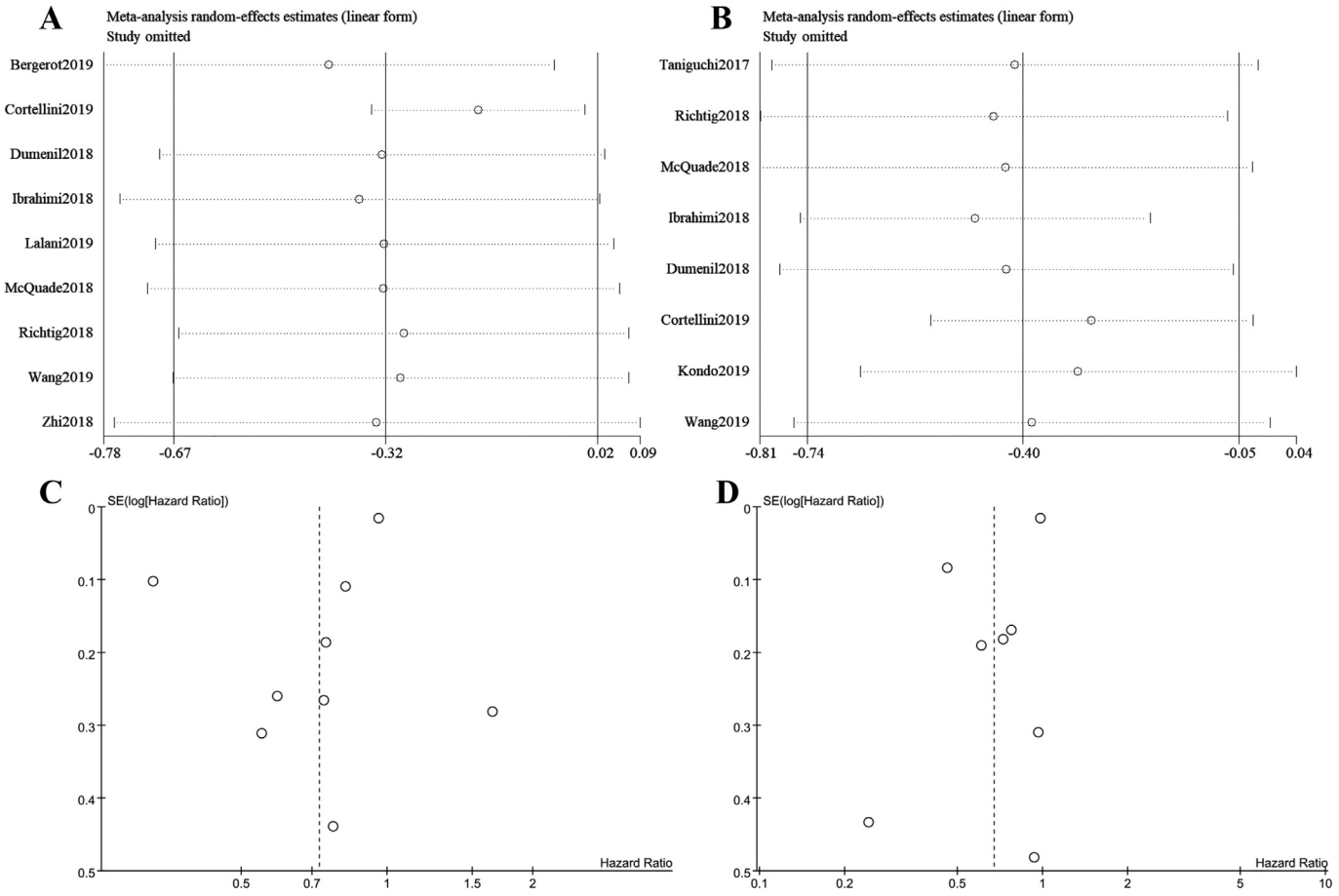

Fig. 6. Sensitivity analysis and funnel plot. A, Sensitivity analysis of OS; B, Sensitivity analysis of PFS; C, Funnel plot of OS; D, Funnel plot of PFS.

reported the relationship between obese and survival of patients with metastatic renal cell carcinoma after ICIs treatment. The value of 25 kg/m^2 was used to define high versus low BMI groups in these studies. They had similar baseline characteristics but with contradictory results. This may be caused by limited sample size from the study of Bergerot [27]. Therefore, it emphasizes the need to verify these results in further clinical studies.

Recently, a meta-analysis [30] suggested that male patients could gain better clinical benefits from ICIs than women. Later, another meta-analysis [31] found the benefits were similar regardless of sex. It seems the prognostic role of sex is still under debate. The relationship between sex, BMI and efficacy of ICIs is still being explored. In our meta-analysis, there were three studies reported the prognostic effect of BMI based on sex. The results showed that males and females shared a similar reduction in risk of death after treating with ICIs. This was not in accordance with the findings of recent individual study [29]. A recent study suggested that the association between obesity and efficacy of ICIs was driven predominantly by males, and the high muscle mass may be one of the reasons that are responsible for the gender-based survival difference [29]. As indicated by the different findings, studies with large sample sizes are warranted to further determine the relationship between gender and efficacy of ICIs in the setting of obesity.

Another concern is about the risk of adverse events in obesity patients who are gaining better treatment response. It is reported that patients with better response from ICIs treatment are suffering increased incidence of adverse events. It is not clear whether these overweight or obesity patients had higher occurrence of adverse events compared to normal BMI patients. From our results, we found that these patients did have a significantly higher risk of adverse events. However, this finding was based on relatively small sample size and limited number of included studies.

Although the results obtained from this study were positive, there were still some limitations. The reasons were as follows: first, the inclusion and exclusion criteria of this study stipulate that this meta-analysis could use information from RCTs and other types of studies, but resulted in only retrospective studies. Secondly, though all the studies used BMI to evaluate the clinical outcomes, the baseline characteristics of these studies were different. The diseases varied among the included studies, including NSCLC, RCC, melanoma, and other types. The treatment procedure and regimen differed between studies. These may be the major reasons causing the heterogeneity. Thirdly, the number of included studies was small, some of the original data was not perfect, and the issue of publication bias needed to be considered. Besides, the relative small sample size of some of the included studies was not ideal for detecting the prognosis of BMI. Finally, the information provided in some studies was not sufficient to calculate HR, so we decided not to include these studies to improve the accuracy of the results, but may result in certain selection bias.

5. Conclusions

The prognostic value of BMI in multiple cancers is further confirmed in this study, so BMI may be a novel prognostic factor for cancer patients treated with ICIs. The results of this study can also provide reference information for clinical oncologists. For obesity patients, the risk of death could be reduced by ICIs treatments regardless of sex. More studies are warranted to validate our findings.

List of abbreviations

ICIs	immune checkpoint inhibitors
OS	overall survival
PFS	progression free survival
BMI	body mass index
NSCLC	non-small cell lung cancer
RCC	renal cell carcinoma
HR	hazard ratio
CI	confidence interval
OR	odds ratio
RR	risk ratio

Ethics approval and informed consent

Not applicable.

Consent for publication

Not applicable.

Data availability

All data generated or analyzed during this study are included in this published article.

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Authors' contributions

HX designed and directed the project. HX and DC searched and identified eligible studies, extracted, analyzed and interpreted the data regarding the disease and BMI. DC and AH performed the quality examination of the included studies, and DC was a major contributor in writing the manuscript. AH and WG examined the combined results. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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