



Relationship between Shift Work and BMI; a Meta-Analysis Study

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ABSTRACT

Aims Obesity is one of the most serious health issues in the world. Various factors such as shift work are known as potential risk factors for obesity. Thus this systematic review and meta-analysis evaluated the associations between shift work and Mean Body Mass Index (BMI).

Information & Methods In October 2020, PubMed, Google Scholar, Scopus, Web of Science, SID, Barakat, IranDoc, and Civilica databases were searched for observational studies in which the relations between the styles of shift works and obesity were investigated. The random-effect model was used to derive the BMI. Subgroup meta-analyses for the study design, particular forms of obesity, and shift work pattern characteristics were performed.

Findings The search resulted in 580 documents, of which 217 articles were identified as eligible papers for the meta-analysis. Overall, the pooled Standard Mean Difference (SMD) and 95% Confidence Interval (CI) for shift work rather than day work was 0.082 (ranging from 0.047 to 0.116). Moreover, the results showed that the mean BMI of all of the styles of shift works (Rotation Shift, SMD (95% CI): 0.099 (0.058, 0.141), Night Shift, SMD (95% CI): 0.079 (0.047, 0.11)), except for evening Shift (SMD (95% CI): 0.041 (-0.061 to 0.142)), are higher than day work.

Conclusion To minimize the harm, companies should provide shift workers with some advice on an appropriate and healthy diet and lifestyle. Companies that provide meals for their employees should consider a different meal plan for shift workers.

Keywords BMI; Obesity; Overweight; Shift Work Schedule; Meta-Analysis

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Introduction

Schedules for shift work are becoming more common amongst different occupations due to the high demand for versatile workers and industrial productivity. Globally, about 20% of the total population [1] is involved in a shift work system. In contrast to daytime work, shift and night work involve a higher risk of cardiovascular diseases and metabolic disorders due to the desynchronization of circadian rhythms that can consequently result in obesity [2-5]. Obesity is an increasingly common disorder regarded as a health concern by many individuals in diverse professions [6, 7]. In addition, excess body fat is a risk factor for respiratory, metabolic, and psychological conditions, which impact the efficiency of jobs. Compared to non-obese workers, obese workers are more vulnerable to infections, absenteeism, and early retirement [8]. Nowadays, several systematic reviews or meta-analysis studies [9-18] have investigated the relationship between working shifts and obesity. But these studies leave out a majority of articles because of different presentations of effect size in the respective published articles. For example, the meta-analyses that have reported qualitative effect size index like Odds Ratio (OR) do not use studies with a quantitative index like Standard Mean Difference (SMD), and vice versa. This problem can lead to publication bias and violation of the meta-analysis results. In this research, regression methods were used to estimate the mean and standard deviation of Body Mass Index (BMI) in the papers that have reported their results qualitatively. Eventually, the pooled meta-analysis results for SMD were reported. According to the importance of this subject, this systematic review and meta-analysis evaluated the associations between work shifts and BMI.

Information and Methods

This meta-analysis started in September 2020 using PubMed, Google Scholar, Scopus, Web of Science, SID (Scientific Information Database), Barakat, IranDoc, and Civilica databases, and it was completed in October 2020. This research included published studies that met all of the following criteria: (1) cross-sectional or cohort studies (only the baseline was used) with the full text of the papers available in the Persian or English language, (2) studies reporting the prevalence of BMI>25kg/m² or BMI>30kg/m² or the mean of BMI according to the shift work schedule. Conversely, the following studies were excluded: (1) non-English or non-Persian full-text reports, (2) letters to the editor, expert opinions, editorials, commentaries, case

reports, case series, and reviews, and (3) studies reporting overlapping data.

To search and include related studies as much as possible, the following terms used: "shift work" OR "Night" OR "Rotation" OR "Evening" AND "Shift" AND Obesity OR "Overweight" OR "BMI", as keywords for titles and/or abstracts in MeSH word search database with such combination.

All of the studies had been performed according to the Declaration of Helsinki, and this article is based on the management plans approved by the educational meeting of Tarbiat Modares University. All published papers categorized as potentially relevant were reviewed separately by both authors. Moreover, the relevance of each report evaluated and summarized the following data using Excel 2010 datasheets: First author's name, year of publication, year of study, mean and standard deviation of BMI, the number of participants that were BMI ≥30kg/m²/BMI ≥ 25kg/m², and the study sample size separated by shift work schedule. This research was conducted according to the preferred reporting items for systematic reviews and meta-analysis (PRISMA) [19], and the paper quality assessment was evaluated by "The Newcastle Ottawa Scale (NOS)" [20]. Furthermore, the extracted data were stratified by the type of work (worker, medical staff, military, employee, driver, and other). A total of 580 studies were potentially associated with the relationship between BMI and shift works. The abstracts and titles have been reviewed, and based on the specified inclusion and exclusion requirements, 99 studies were excluded. A total of 217 records of eligible published studies until 2020 [21-237] were considered after full-text scanning and quality evaluation (Table 1). The selection process of the study is represented in Figure 1.

The statistical analysis of this study was done in two stages. In stage 1, the mean and the SD of the articles that reported the prevalence of BMI>25 kg/m² and BMI>30 kg/m² (not reported mean and SD) were estimated by regression analysis ($R^2=70\%$). In stage 2, the pooled Standard Mean Difference (SMD) of each kind of shift work, in comparison with day work, were calculated using the random effect model. The statistical tests of heterogeneity among the studies were carried out using the Q test ($p<0.01$ indicates statistically significant heterogeneity) and I-squared statistics. Publication bias was assessed graphically and statistically by funnel plot and based on visual inspection of the funnel plot, Begg's Test, and Egger's test. In this study, the SMD was reported based on different types of work (worker, medical staff, military, employee, driver, and others). The "metaphor" package in R 3.6 software was used for data analysis.

Table 1) Characteristics of the included published style shift articles in the field of BMI

Reference	(Sample Size, Mean Age, Male Percent, Mean±SD of BMI)
[21]	D:(43,30,%0,26.7±8.2); E:No; N:No; R:(57,30,%0,26.3±4.4); S:No
[22]	D:(183,42,%0,24.3±3.86); E:No; N:No; R:No; S:(506,42,%0,24.9±4.13)
[23]	D:(47,35,%0,21.3±2.6); E:No; N:No; R:No; S:(36,39,%0,21.6±2.9)
[24]	D:(22045,43,%0,23.5±8); E:No; N:No; R:(28442,43,%0,24.4±8.5); S:No
[25]	D:(102,52,%57,27.4±5.18); E:No; N:No; R:No; S:(118,52,%34,27±4.98)
[26]	D:(1483,35,%4,24.8±4.06); E:(482,36,%6,26.4±4.74); N:(124,36,%4,26.4±4.74); R:No; S:No
[27]	D:(36,39,%0,24.8±3.8); E:No; N:No; R:No; S:(116,39,%0,23.1±3.6)
[28]	D:(28015,43,%0,25.4±4.8); E:No; N:No; R:(41408,43,%0,26.4±4.9); S:No
[29]	D:(57728,37,%0,21.5±2.72); E:No; N:No; R:No; S:(14249,37,%0,21.6±2.74)
[30]	D:(23367,47,%0,25.1±4.6); E:No; N:(40902,47,%0,25.9±6.9); R:No; S:No
[31]	D:(35,40,%0,22.1±5.76); E:No; N:No; R:(40,41,%0,23±5.92); S:No
[32]	D:(1259,45,%0,24.4±3.9); E:No; N:No; R:No; S:(1235,45,%0,24.6±3.99)
[33]	D:(151,35,%0,23.6±3.56); E:No; N:(172,35,%0,24.7±4.04); R:No; S:No
[34]	D:(280,35,%9,25.7±4.46); E:No; N:(166,35,%4,25.7±4.44); R:No; S:No
[35]	D:(370,50,%0,25.2±4.26); E:No; N:No; R:(354,50,%0,25.2±4.26); S:No
[36]	D:(319,50,%0,27.2±4.7); E:No; N:No; R:(321,50,%0,27.1±4.7); S:No
[37]	D:(1212,45,%0,24.4±3.91); E:No; N:(115,45,%0,24.4±3.93); R:(759,45,%0,24.6±4.01); S:No
[38]	D:(183,46,%0,26.6±6.88); E:No; N:No; R:No; S:(1194,46,%0,28±5.74)
[39]	D:(359,50,%0,27.1±4.7); E:No; N:No; R:(349,50,%0,27.1±4.6); S:No
[40]	D:(17,46,%0,27.8±7.15); E:No; N:(57,46,%0,26.4±4.8); R:No; S:No
[41]	D:(4702,30,%0,21.4±2.6); E:No; N:No; R:No; S:(5287,30,%0,20.5±2.5)
[42]	D:(158,39,%100,26.9±4.94); E:No; N:(185,39,%100,27.2±5.06); R:No; S:No
[43]	D:(55,38,%0,25.4±4.33); E:No; N:No; R:No; S:(43,38,%0,24.1±3.8)
[44]	D:(2825,40,%0,25.2±4.78); E:(830,40,%0,25±4.89); N:(899,40,%0,25.8±4.79); R:No; S:No
[45]	D:(14,39,%0,22.6±3.4); E:No; N:No; R:No; S:(13,39,%0,22.5±2.6)
[46]	D:(371,50,%0,25.2±4.26); E:No; N:(354,50,%0,25.2±4.26); R:No; S:No
[47]	D:(5480,60,%0,24.7±3.97); E:No; N:No; R:No; S:(1812,60,%0,24.9±4.07)
[48]	D:(1179,40,%0,20.5±2.3); E:No; N:No; R:No; S:(1579,40,%0,20.8±2.9)
[49]	D:(370,50,%0,27±4.7); E:No; N:No; R:(354,50,%0,27.1±4.7); S:No
[50]	D:(568,42,%7,24.4±4.1); E:No; N:(1491,42,%11,24.5±6.18); R:No; S:No
[51]	D:(170,50,%0,26.7±4.4); E:No; N:(218,50,%0,26.1±4.1); R:No; S:No
[52]	D:(29328,63,%0,26.4±5.2); E:No; N:(42529,63,%0,27.3±5.5); R:No; S:No
[53]	D:(30,38,%0,23±2); E:No; N:No; R:No; S:(30,35,%0,23±2)
[54]	D:(15391,55,%0,27±6); E:No; N:(39333,54,%0,28.1±6.7); R:No; S:No
[55]	D:(12414,51,%0,23.6±3.57); E:(2022,53,%0,23.3±3.45); N:(1098,51,%0,23.8±3.67); R:(4330,53,%0,23.6±3.56); S:No
[56]	D:(174,33,%0,22.5±4); E:No; N:No; R:No; S:(57,33,%0,23.1±4.2)
[57]	D:(258,48,%0,25.9±4.51); E:No; N:No; R:No; S:(114,48,%0,26.1±4.62)
[58]	D:(154,46,%0,26.8±4.5); E:No; N:(191,46,%0,26.2±4.4); R:No; S:No
[59]	D:(39,42,%0,21.7±2.7); E:No; N:No; R:No; S:(123,42,%0,21.7±3.5)
[60]	D:(50,43,%0,27.2±6.6); E:No; N:(53,34,%0,28.4±7.1); R:No; S:No
[61]	D:(40529,34,%0,25±5.3); E:No; N:(12093,34,%0,26±5.8); R:No; S:No
[62]	D:(64,35,%0,24.9±4.11); E:No; N:(86,35,%0,25.4±4.34); R:No; S:No
[63]	D:(11272,40,%0,23.6±3.57); E:(1805,40,%0,23.3±3.45); N:(980,40,%0,24±3.73); R:(3958,40,%0,23.6±3.57); S:No
[64]	D:(8,34,%0,28.5±8.4); E:No; N:No; R:No; S:(9,29,%0,27.7±5.7)
[65]	D:(84,42,%8,26.2±5.2); E:No; N:(71,42,%11,25.5±5.2); R:No; S:No
[66]	D:(29,37,%32,25.6±5.4); E:No; N:(13,27,%24,27.7±2.45); R:(68,39,%28,26.7±4.75); S:No
[67]	D:(65,42,%11,24.3±3.6); E:No; N:(788,42,%12,25±4.1); R:No; S:No
[68]	D:(44,34,%39,23.8±2.6); E:No; N:No; R:No; S:(44,34,%28,24.5±3.2)
[69]	D:(38,35,%0,23.8±3.69); E:No; N:No; R:No; S:(176,37,%0,23.4±3.58)
[70]	D:(22603,43,%0,25.1±4.6); E:No; N:No; R:No; S:(32721,43,%0,25.8±4.9)
[71]	D:(269,43,%0,29.5±6.02); E:No; N:No; R:No; S:(725,43,%0,22.7±3.22)
[72]	D:(1095,40,%0,21.2±2.7); E:No; N:No; R:(1464,40,%0,21.6±3.2); S:No
[73]	D:(20,46,%0,27.4±5.3); E:No; N:No; R:No; S:(20,44,%0,30±8.4)
[74]	D:(51,38,%0,22.3±3.3); E:No; N:(46,38,%0,23.2±3); R:No; S:No
[75]	D:(194,36,%0,26.8±4.93); E:No; N:No; R:No; S:(454,36,%0,25.9±4.53)
[76]	D:(89,43,%0,24.9±4.2); E:No; N:(36,43,%0,23.2±3.9); R:No; S:
[77]	D:(354,40,%6,24.9±4.1); E:No; N:No; R:No; S:(1150,40,%7,25±4.18)
[78]	D:(93,46,%12,25.3±4.3); E:No; N:No; R:No; S:(503,40,%17,25.3±4.2)
[79]	D:(271,55,%0,25±4.17); E:No; N:No; R:(251,53,%0,25.5±4.38); S:No
[80]	D:(46,34,%0,26.3±6.3); E:No; N:(84,34,%0,27.9±6.8); R:No; S:No
[81]	D:(40,51,%0,26.7±5.1); E:No; N:No; R:No; S:(32,41,%0,28.9±6)
[82]	D:(15,39,%0,23.5±3); E:No; N:(15,39,%0,24.5±5.54); R:No; S:No
[83]	D:(4760,44,%0,25±5); E:No; N:(567,41,%0,26.5±5.8); R:No; S:No
[84]	D:(12,33,%100,28.2±3.1); E:No; N:(12,37,%100,30.6±4); R:No; S:No
[85]	D:(200,35,%100,22.9±3.28); E:No; N:No; R:No; S:(200,35,%100,23.1±3.36)
[86]	D:(240,44,%100,25.9±3.3); E:No; N:No; R:No; S:(361,43,%100,25.8±3.4)
[87]	D:(13,26,%100,22.6±2.2); E:No; N:No; R:No; S:(12,21,%100,24.5±3.3)
[88]	D:(70,32,%100,24.7±7.94); E:No; N:No; R:No; S:(71,32,%100,24.6±3.95)
[89]	D:(239,37,%100,22.4±3.09); E:No; N:No; R:No; S:(60,37,%100,25.1±4.22)
[90]	D:(26,24,%100,23.3±2.8); E:No; N:No; R:No; S:(27,24,%100,23.1±2.7)
[91]	D:(44,25,%0,20.1±1.04); E:No; N:No; R:No; S:(47,25,%0,21.4±2.53)
[92]	D:(2824,45,%100,23.1±3); E:No; N:No; R:No; S:(826,45,%100,23.1±2.8)

Continue of Table 1 Characteristics of the included published style shift articles in the field of BMI

Reference	(Sample Size, Mean Age, Male Percent, Mean±SD of BMI)
[93]	D:(42,33,%100,24.9±2.8); E:(56,34,%100,23.8±2.5); N:(34,32,%100,23.4±2.2); R:No; S:No
[94]	D:(665,43,%100,25±4.1); E:No; N:No; R:No; S:(659,43,%100,25±4.13)
[95]	D:(3658,39,%0,23.1±3.35); E:No; N:No; R:No; S:(585,39,%0,23.3±3.47)
[96]	D:(14774,60,%100,23±3.9); E:No; N:(864,60,%100,23.3±2.8); R:(2011,60,%100,23.2±2.7); S:No
[97]	D:(920,40,%47,25.4±4.6); E:No; N:No; R:No; S:(130,40,%50,25.1±4.3)
[98]	D:(3203,35,%100,23.4±2.9); E:No; N:No; R:No; S:(2426,35,%100,23.2±2.8)
[99]	D:(712,34,%100,22.4±2.76); E:No; N:No; R:No; S:(434,34,%100,22.4±2.99)
[100]	D:(1235,42,%100,25.3±4.1); E:No; N:(1093,42,%100,27±4.55); R:No; S:No
[101]	D:(3263,35,%100,23.2±2.83); E:No; N:No; R:No; S:(2247,36,%100,22.9±2.81)
[102]	D:(1305,40,%100,22.8±2.7); E:No; N:No; R:No; S:(623,40,%100,23±3.1)
[103]	D:(72,35,%100,23.6±2.86); E:No; N:No; R:No; S:(76,35,%100,23.6±3.82)
[104]	D:(3963,35,%100,23.4±2.9); E:No; N:No; R:No; S:(2748,36,%100,23.2±2.9)
[105]	D:(4328,37,%100,23.5±2.9); E:No; N:No; R:No; S:(2926,37,%100,23.3±3)
[106]	D:(4079,36,%100,23.5±2.9); E:No; N:No; R:No; S:(2807,36,%100,23.3±3)
[107]	D:(98,50,%100,26.4±3.26); E:No; N:No; R:No; S:(100,50,%100,26.3±3.4)
[108]	D:(13,43,%0,23.7±3.55); E:No; N:(14,43,%15,29.2±5.3); R:No; S:No
[109]	D:(17842,46,%89,25.9±4.49); E:No; N:(1564,46,%89,26.7±4.85); R:(7036,46,%89,26.3±4.68); S:No
[110]	D:(876,35,%0,22.1±3.42); E:No; N:(651,33,%0,22.6±4.3); R:No; S:No
[111]	D:(15536,42,%49,24.5±3.97); E:No; N:(332,42,%32,24.4±3.91); R:No; S:(1210,42,%42,23.9±3.72)
[112]	D:(7,30,%100,27.2±2.64); E:No; N:(9,30,%100,26.1±4.2); R:No; S:No
[113]	D:(7,27,%100,27.2±2.64); E:No; N:(9,27,%100,26.1±4.2); R:No; S:No
[114]	D:(6,42,%100,23.6±1.5); E:No; N:(4,42,%100,22.6±1.1); R:(4,42,%100,23.6±1.5); S:No
[115]	D:(5719,42,%36,24.8±4.02); E:No; N:No; R:No; S:(993,42,%45,24.9±4.09)
[116]	D:(89,41,%100,25.9±10.49); E:No; N:No; R:No; S:(33,41,%100,26.7±9.54)
[117]	D:(200,48,%100,26.2±4.62); E:No; N:No; R:No; S:(200,48,%100,27±4.95)
[118]	D:(4079,36,%100,27.1±2.1); E:No; N:No; R:No; S:(2807,36,%100,27.2±2.1)
[119]	D:(247,43,%27,26.9±4.9); E:No; N:No; R:No; S:(234,44,%23,27.4±4.8)
[120]	D:(406,34,%32,29.3±5.93); E:No; N:(800,34,%36,23.1±3.39); R:No; S:No
[121]	D:(229,45,%100,26.7±3.6); E:No; N:(110,44,%100,27.6±3.9); R:No; S:No
[122]	D:(17345,64,%44,23.9±5.1); E:No; N:No; R:No; S:(9118,64,%45,23.8±5.1)
[123]	D:(50,33,%100,22.7±1.06); E:No; N:No; R:No; S:(50,33,%100,25.4±1.78)
[124]	D:(252,45,%100,24±3.75); E:No; N:No; R:No; S:(223,45,%100,24.2±3.85)
[125]	D:(9209,24,%100,21.7±2.5); E:No; N:No; R:No; S:(964,22,%100,21.6±2.7)
[126]	D:(12,35,%0,27.4±1.12); E:No; N:(12,37,%0,28.3±1.24); R:No; S:No
[127]	D:(71,47,%0,22.4±3.7); E:No; N:No; R:No; S:(183,47,%0,23.9±2.9)
[128]	D:(325,34,%33,24.6±3.95); E:No; N:(580,34,%33,24.7±4); R:No; S:No
[129]	D:(111,40,%100,29.3±5.95); E:No; N:No; R:No; S:(159,40,%100,29.2±5.92)
[130]	D:(3094,44,%77,22.7±3.06); E:No; N:(1017,44,%93,23.3±3.37); R:No; S:No
[131]	D:(207,35,%100,23.4±2.78); E:No; N:No; R:No; S:(209,37,%100,26.2±9.54)
[132]	D:(2257,35,%100,24.6±3.18); E:(2854,34,%100,24±2.92); N:(362,35,%100,24.5±3.14); R:No; S:No
[133]	D:(2410,40,%45,24.9±4.11); E:No; N:(2459,40,%54,24.6±4.01); R:No; S:No
[134]	D:(262,41,%100,25.9±3.14); E:No; N:No; R:(278,42,%100,26.8±3.45); S:No
[135]	D:(757,43,%99,23.3±3.47); E:No; N:No; R:No; S:(897,43,%93,23.9±3.7)
[136]	D:(12005,37,%86,26.1±4); E:No; N:(3568,41,%95,28±4.3); R:(198,40,%99,27.9±4.5); S:No
[137]	D:(3406,25,%100,23.2±3.4); E:No; N:No; R:No; S:(1348,25,%100,23.2±3.41)
[138]	D:(5577,45,%100,24±2.6); E:No; N:(462,45,%100,23.9±2.4); R:No; S:No
[139]	D:(99,36,%20,25±4.1); E:No; N:No; R:No; S:(101,34,%20,25±3.7)
[140]	D:(33,45,%79,25.8±2.8); E:No; N:(27,43,%63,26.8±5.1); R:No; S:No
[141]	D:(70,47,%100,24.7±2.8); E:No; N:No; R:No; S:(40,45,%100,25.5±3)
[142]	D:(112,30,%100,24.2±2.8); E:No; N:(46,30,%100,24±2.4); R:No; S:(86,30,%100,24.4±2.5)
[143]	D:(35234,47,%0,23.1±3.38); E:No; N:No; R:No; S:(7000,47,%0,23.2±3.42)
[144]	D:(652,40,%100,26±3.5); E:No; N:No; R:(183,40,%100,25.7±3.4); S:(791,40,%100,26.2±3.3)
[145]	D:(5635,38,%78,24±3.76); E:No; N:No; R:No; S:(8469,38,%34,23.1±3.36)
[146]	D:(1321,46,%100,24±3.75); E:No; N:No; R:No; S:(1171,45,%100,25.7±4.44)
[147]	D:(862,42,%100,25.6±3.8); E:No; N:No; R:No; S:(870,42,%100,26±4)
[148]	D:(200,35,%100,22.9±3.28); E:No; N:No; R:No; S:(200,35,%100,23.1±3.36)
[149]	D:(878,43,%100,24.2±2.4); E:No; N:No; R:No; S:(1075,42,%100,24.4±2.5)
[150]	D:(578,33,%100,25.1±3.47); E:No; N:No; R:(790,33,%100,25.3±3.56); S:No
[151]	D:(7531,31,%0,24±7.6); E:No; N:(11193,30,%0,23.9±7.9); R:No; S:No
[152]	D:(3060,40,%100,26.5±3.6); E:No; N:No; R:No; S:(3479,40,%100,26.5±3.7)
[153]	D:(534,43,%54,27.1±4.7); E:No; N:(74,43,%77,27.2±4.6); R:No; S:No
[154]	D:(806,47,%40,24.6±3.98); E:(128,43,%44,25.3±4.29); N:(74,44,%50,25.7±4.44); R:No; S:No
[155]	D:(36,47,%100,26.4±4.76); E:(19,47,%100,26.9±4.95); N:(44,47,%100,26.6±4.82); R:No; S:No
[156]	D:(8007,51,%42,26.7±4.53); E:No; N:(1778,51,%49,27.1±4.49); R:No; S:No
[157]	D:(1677,40,%96,24.3±3.86); E:No; N:(1757,40,%80,23.6±3.57); R:No; S:No
[158]	D:(2840,48,%60,24.4±3.93); E:No; N:No; R:No; S:(664,48,%75,24.6±3.99)
[159]	D:(418,42,%28,23.6±3.59); E:No; N:No; R:No; S:(70,42,%29,24.2±3.82)
[160]	D:(8053,46,%51,24.2±3.84); E:No; N:No; R:No; S:(1052,45,%68,24.3±3.88)
[161]	D:(100,33,%0,21.9±3.1); E:(100,33,%0,21.1±2.1); N:(100,32,%0,21.7±2.6); R:No; S:No
[162]	D:(4095,46,%26,23.8±3.7); E:No; N:No; R:No; S:(1253,46,%12,23.6±3.75)
[163]	D:(652,42,%100,26±3.51); E:No; N:No; R:(183,42,%100,26.2±3.26); S:No
[164]	D:(21,43,%0,26.9±5.5); E:No; N:(69,43,%0,26.6±5.2); R:No; S:No

Continue of Table 1 Characteristics of the included published style shift articles in the field of BMI

Reference	(Sample Size, Mean Age, Male Percent, Mean±SD of BMI)
[165]	D:(5609,68,43,%56,24.7±4.02); E:No; N:(70450,43,%76,25.1±4.18); R:No; S:No
[166]	D:(42,44,%100,26.5±6.54); E:No; N:(37,43,%100,27.2±7.44); R:No; S:No
[167]	D:(2866,32,%100,23.9±2.9); E:No; N:(1874,30,%100,23.7±3); R:No; S:No
[168]	D:(94,40,%30,26.3±4.6); E:No; N:(106,46,%31,28.4±4.9); R:No; S:No
[169]	D:(104,49,%0,27.4±5.5); E:No; N:(90,50,%0,27.7±6.38); R:No; S:No
[170]	D:(3930,39,%0,22.5±3.11); E:No; N:(250,39,%0,22.4±3.06); R:No; S:No
[171]	D:(17,39,%6,30.7±9.48); E:No; N:No; R:No; S:(33,36,%6,29±6.31)
[172]	D:(4848,46,%100,26±3.8); E:No; N:No; R:No; S:(2569,46,%100,27.2±3.9)
[173]	D:(7853,46,%75,27.6±2.26); E:No; N:(1390,43,%61,27.9±2.52); R:No; S:No
[174]	D:(5326,40,%54,24.9±3.5); E:No; N:No; R:No; S:(2675,40,%52,25.2±3.75)
[175]	D:(238,41,%100,25.7±4.17); E:No; N:No; R:No; S:(212,41,%100,30.4±4.1)
[176]	D:(4512,65,%46,24.2±3.3); E:No; N:No; R:No; S:(2941,63,%46,24.2±3.3)
[177]	D:(22,41,%100,25.6±3.77); E:No; N:No; R:No; S:(30,41,%100,27.3±3.6)
[178]	D:(1090,40,%100,25.7±3.7); E:No; N:No; R:No; S:(1384,40,%100,26.7±4.09)
[179]	D:(26,43,%100,24.7±4.06); E:No; N:No; R:No; S:(31,43,%100,26.3±4.71)
[180]	D:(69,47,%100,27.9±4.2); E:No; N:(81,44,%100,28.9±3.4); R:No; S:No
[181]	D:(26,39,%100,26.4±4.74); E:No; N:(31,40,%100,28.4±5.57); R:No; S:No
[182]	D:(134,48,%100,26.5±2.7); E:No; N:No; R:No; S:(185,48,%100,27.7±3.4)
[183]	D:(1220,47,%100,25.2±3.2); E:No; N:No; R:(309,47,%100,25.8±3); S:No
[184]	D:(615,31,%100,24.1±2.65); E:No; N:No; R:(381,32,%100,23.9±2.9); S:No
[185]	D:(17218,38,%100,24.6±3.95); E:No; N:No; R:(14128,38,%100,25.3±4.25); S:No
[186]	D:(255,34,%100,26.2±4.5); E:No; N:No; R:(184,36,%100,27±4.6); S:No
[187]	D:(1700,49,%100,23.8±3.2); E:No; N:No; R:No; S:(1125,49,%100,23.4±3.5)
[188]	D:(8992,24,%100,21.2±1.8); E:No; N:No; R:(920,24,%100,22.2±4); S:No
[189]	D:(2511,45,%0,24.7±4.03); E:No; N:(1525,45,%0,24.6±3.99); R:No; S:No
[190]	D:(89,48,%69,25.3±4.28); E:No; N:(78,48,%59,25.7±4.45); R:No; S:No
[191]	D:(11699,55,%58,27±4.65); E:No; N:(5777,55,%51,27.5±4.6); R:No; S:No
[192]	D:(147,45,%0,27±6); E:No; N:No; R:No; S:(114,40,%0,28.5±6.6)
[193]	D:(67,45,%100,26.1±4.62); E:No; N:No; R:No; S:(384,45,%100,26.1±4.63)
[194]	D:(8169,55,%44,26±3.62); E:No; N:(684,55,%44,26.3±2.65); R:No; S:No
[195]	D:(2661,30,%61,23.5±7.2); E:No; N:No; R:No; S:(656,30,%57,23.6±7.08)
[196]	D:(436,42,%99,25.7±4.45); E:No; N:No; R:No; S:(265,42,%98,26.2±4.64)
[197]	D:(152,44,%0,27±6.03); E:No; N:No; R:No; S:(142,38,%0,27.8±6)
[198]	D:(117,32,%100,25.1±8.6); E:No; N:No; R:No; S:(286,33,%100,24.8±10.14)
[199]	D:(63,40,%47,26.8±3.6); E:No; N:No; R:(61,40,%53,26.7±4.1); S:No
[200]	D:(1380,38,%86,25.7±3.97); E:No; N:No; R:No; S:(1683,36,%96,25.5±3.64)
[201]	D:(158839,55,%47,27.1±4.6); E:No; N:(4342,55,%64,28.6±4.8); R:No; S:No
[202]	D:(12927,40,%51,24.9±4.1); E:No; N:No; R:No; S:(4053,40,%51,24.6±3.99)
[203]	D:(269,39,%73,24.4±3.43); E:No; N:No; R:No; S:(155,39,%89,25.6±4.01)
[204]	D:(135,32,%100,27±3.8); E:No; N:No; R:No; S:(89,31,%100,26.8±3.45)
[205]	D:(37,40,%100,24.3±3); E:No; N:No; R:No; S:(59,40,%100,25.3±3.05)
[206]	D:(19576,45,%50,24.6±3.93); E:No; N:No; R:No; S:(7209,45,%36,24.9±4.09)
[207]	D:(150,37,%41,23±3.32); E:No; N:No; R:No; S:(227,37,%55,22.5±3.13)
[208]	D:(877,34,%100,26.3±5.9); E:No; N:No; R:No; S:(474,36,%100,27.1±6.5)
[209]	D:(884,46,%46,35.3±9); E:(99,43,%24,38.7±9.6); N:No; R:(292,45,%56,35.2±9.8); S:No
[210]	D:(10252,51,%0,24±3.74); E:No; N:(3404,51,%0,24.1±3.8); R:No; S:No
[211]	D:(1263,55,%74,23.5±3.53); E:No; N:No; R:No; S:(279,55,%75,24.8±4.06)
[212]	D:(1162,42,%52,28.4±10.2); E:(68,39,%56,27.4±8.2); N:(50,38,%59,29.4±6.3); R:(101,38,%56,28.2±9); S:No
[213]	D:(17722,48,%0,29±5.82); E:No; N:(10319,46,%0,30±6.32); R:No; S:No
[214]	D:(7173,43,%28,24.8±4.09); E:No; N:No; R:No; S:(683,43,%46,25.1±4.22)
[215]	D:(3755,34,%53,27.1±12.25); E:No; N:No; R:No; S:(568,34,%54,26.6±8.34)
[216]	D:(7140,47,%54,24.8±4.07); E:No; N:No; R:No; S:(1019,47,%54,24.7±4.03)
[217]	D:(489,63,%50,27.1±5.05); E:No; N:No; R:No; S:(106,63,%46,38.7±9.85)
[218]	D:(3561,40,%56,23.9±3.4); E:No; N:No; R:No; S:(370,40,%56,23.8±3.5)
[219]	D:(4360,43,%39,25.6±4.5); E:(284,43,%26,25.2±4.5); N:(113,43,%37,26.6±4.8); R:No; S:No
[220]	D:(85,52,%43,28.6±5); E:No; N:(60,47,%50,29.6±6.1); R:No; S:No
[221]	D:(8,25,%50,22.8±2.8); E:No; N:(9,26,%44,21.8±3.6); R:No; S:No
[222]	D:(808,40,%0,24.2±2.8); E:No; N:No; R:No; S:(125,40,%0,24.4±3)
[223]	D:(224928,46,%46,27±4.6); E:No; N:(47286,51,%46,28.1±4.9); R:No; S:No
[224]	D:(210,33,%0,25.7±4.47); E:No; N:No; R:No; S:(209,33,%0,25.1±4.22)
[225]	D:(8253,50,%33,28.5±6); E:No; N:No; R:No; S:(4155,50,%33,28.8±6.4)
[226]	D:(298,42,%56,25±4.17); E:No; N:(138,42,%56,25.2±4.23); R:No; S:No
[227]	D:(140,40,%64,24.5±3.82); E:No; N:No; R:No; S:(292,39,%97,25.7±3.3)
[228]	D:(498,48,%47,31.1±7.3); E:(131,48,%30,33.9±9.7); N:No; R:No; S:No
[229]	D:(233,50,%100,25.2±4.26); E:No; N:(66,50,%100,25.5±4.36); R:No; S:No
[230]	D:(266,43,%100,25.6±3.74); E:No; N:No; R:No; S:(158,43,%100,25.6±3.43)
[231]	D:(180,47,%58,28.4±4.27); E:No; N:No; R:No; S:(164,47,%86,28.1±4.5)
[232]	D:(40,44,%100,29.4±6); E:No; N:(41,35,%100,28.3±5.54); R:No; S:No
[233]	D:(6198,42,%38,28.5±10.2); E:No; N:No; R:No; S:(1445,37,%53,28.7±8.7)
[234]	D:(50,36,%100,23.1±1.26); E:No; N:No; R:No; S:(50,37,%100,27.1±1.94)
[235]	D:(180,47,%57,28.6±4.8); E:(102,47,%92,30.4±4.2); N:(81,47,%79,29±4.9); R:No; S:No
[236]	D:(40,33,%100,22.2±1.26); E:No; N:No; R:No; S:(40,33,%100,26.8±2.87)
[237]	D:(35,38,%100,22.7±3.22); E:No; N:No; R:No; S:(35,38,%100,24.9±4.89)

D: Day worker; E: Evening shift; N: Night shift; R: Rotation; S: Shift work

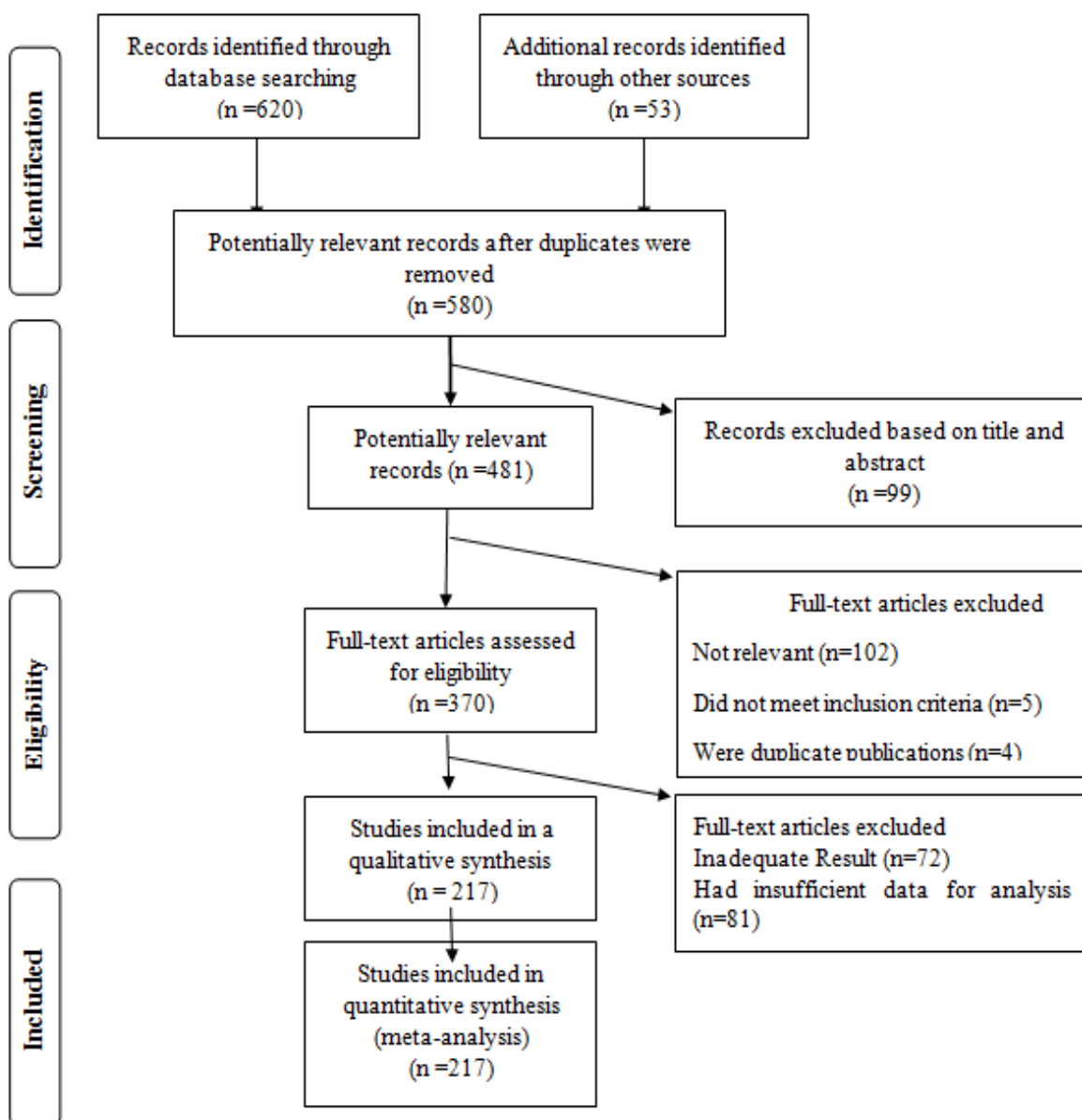


Figure 1) The process of article searching based on PRISMA guidelines

Findings

The total number of studies used for investigating the effects of shift works in BMI were 217.

In comparison with day work, the pooled BMI's SMD of different types of shift work (evening, night, rotation, and overall shifts) was reported in Table 2.

The pooled SMD and 95% Confidence Interval (CI) for shift work, rather than day work, was 0.082 (ranging from 0.047 to 0.116). Moreover, the results

showed that the mean BMI of every style of shifts (rotation shift, SMD (95% CI): 0.099 (0.058, 0.141), night shift, SMD (95% CI): 0.079 (0.047, 0.11)), except for evening shift (SMD (95% CI): 0.041 (-0.061 to 0.142)), were higher than day work. Additionally, the results also indicated that the highest SMD was in military staff and drivers. In Table 3, the publication bias test according to the shift group was reported. Publication bias did not exist in this meta-analysis considering ($p > 0.05$).

Table 2) The pooled standard difference of BMI according to the types of shift and work

Shift Group	Type of Work	Pooled Analysis				Q Test	I ²	τ ²	Z	p-value
		N	SMD	Confidence Interval						
				Lower	Upper					
Evening Shift	Worker	5	-0.127	-0.341	0.087	17.74	77.50%	0.039	1.16	0.245
	Medical	4	0.039	-0.114	0.191	69.3	95.70%	0.023	0.5	0.618
	Military	1	0.392	0.147	0.637	-	-	-	3.13	0.002
	Other Work	4	0.134	-0.134	0.402	25.2	88.10%	0.065	0.98	0.327
	Total	14	0.041	-0.061	0.142	155.93	91.70%	0.027	0.78	0.433
Rotation Shift	Worker	8	0.117	0.04	0.194	36.28	80.70%	0.0072	2.99	0.003
	Medical	14	0.064	0.003	0.124	226.6	94.30%	0.0085	2.06	0.04
	Employee	6	0.169	0.012	0.327	88.22	94.30%	0.0323	2.1	0.035
	Other Work	2	-0.014	-0.124	0.097	0.01	0.00%	0.000	0.24	0.811
	Total	30	0.099	0.058	0.141	407.3	92.90%	0.0085	4.67	<0.001
Night Shift	Worker	36	0.031	-0.041	0.103	1172.18	97.00%	0.034	0.83	0.404
	Medical	29	0.128	0.099	0.157	111.28	74.80%	0.0019	8.59	<0.001
	Employee	6	0.088	-0.052	0.229	218.41	97.70%	0.0278	1.23	0.218
	Military	2	0.004	-0.238	0.246	1.1	9.30%	0.0035	0.04	0.972
	Driver	3	0.283	0.074	0.492	0.17	0.00%	0.000	2.65	0.008
	Other Work	9	0.147	0.073	0.22	104.61	92.40%	0.0061	3.93	<0.001
	Total	85	0.079	0.047	0.11	2127.29	96.10%	0.0123	4.92	<0.001
Shift	Worker	56	0.079	0.035	0.122	926.99	94.10%	0.0206	3.55	<0.001
	Medical	26	-0.065	-0.164	0.035	1003.86	97.50%	0.0466	1.27	0.203
	Employee	12	0.04	-0.031	0.111	44.97	75.50%	0.0089	1.11	0.267
	Military	6	0.76	0.274	1.245	141.14	96.50%	0.3324	3.07	0.002
	Driver	3	0.251	0.173	0.329	0.68	0.00%	0.000	6.31	<0.001
	Other Work	15	0.175	0.075	0.275	282.39	95.00%	0.0325	3.42	0.001
	Total	118	0.082	0.047	0.116	2536.46	95.40%	0.0268	4.61	<0.001

Table 3) The publication Bias test according to the shift group

Shift Group	Begg's Test		Egger's test	
	Z	p-Value	Z	p-Value
Evening Shift	-0.27	0.784	-1.58	0.139
Rotation	-1.48	0.139	1.21	0.235
Night	-1.92	0.054	1.66	0.102
Shift	-2.65	0.008	-1.48	0.142

Discussion

Nowadays, due to the increasing demand for products and services, shift works are considered inevitable in the industry, health, and services. In this regard, recognizing the adverse effects of shift works on health can allow researchers to control this emerging phenomenon. One of the possible adverse effects of shift works is weight gain and obesity. Since different studies have reported contradictory statements on the relationship between shift work and weight, this study was conducted to investigate the relationship between shift work and BMI as an indicator of general obesity [15].

This study showed that military staff and drivers have the highest risk of obesity in shift workers compared to day workers. The highest difference in terms of SMD index among the three types of shifts studied was observed among workers with changing shift patterns, and the lowest was reported for evening shift workers. Therefore, the risk of obesity among workers with changing shift patterns was higher than the evening and night shift workers. Generally, the results of this study indicated that shift work increases the average obesity of shift

workers compared to day workers. These results are consistent with those of the Liu *et al.* [16] study and Sun *et al.* [18] study and inconsistent with those of the Chang & Jen [9] study. In detail, Liu *et al.* showed a 12% increase in the risk of obesity in the night shift compared to day workers. Moreover, Sun *et al.* showed that night shifts increase obesity by 23% compared to other shifts.

There are several ways to justify the observations between shift work and BMI. One could be based on more food consumption and more stress, and less activity and mobility in shift workers than day workers. Another justification could be based on the changes in the sleep cycles of shift workers. Indeed, circadian desynchronization, as it occurs in shift workers, is associated with cardio-metabolic alterations [238] and an increased risk of metabolic syndromes and cardiovascular diseases [107, 183, 239, 240]. Based on the link between circadian desynchrony and obesity and metabolic disorders, obesity could be regarded as a 'chronobiological disease' [240, 241].

The main limitation of the present study was not using the Multivariate Meta method for better results. Also, there are some positive points in this analysis that should be considered. The obtained studies were used as much as possible, and no study was omitted in this process, and the studies that lacked enough information, their information were estimated using regression methods. Another advantage of this study was the examination of obesity in different occupational groups.

Conclusion

According to the result of this study, to minimize the harm, companies should provide shift workers with some advice on an appropriate and healthy diet and lifestyle. Companies that provide meals for their employees should consider a different meal plan for shift workers.

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Ethical Permissions: It was approved by Tarbiat Modares University with IR.MODARES.REC.1399.016 ethics code on May 16, 2020.

Conflicts of Interests: -

Authors' Contribution: Molaei A. (First Author), Introduction Writer/Assistant Researcher/Statistical Analyst (50%); Gholami Fesharaki (Second Author), Methodologist/Main Researcher/Discussion Writer (50%).

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